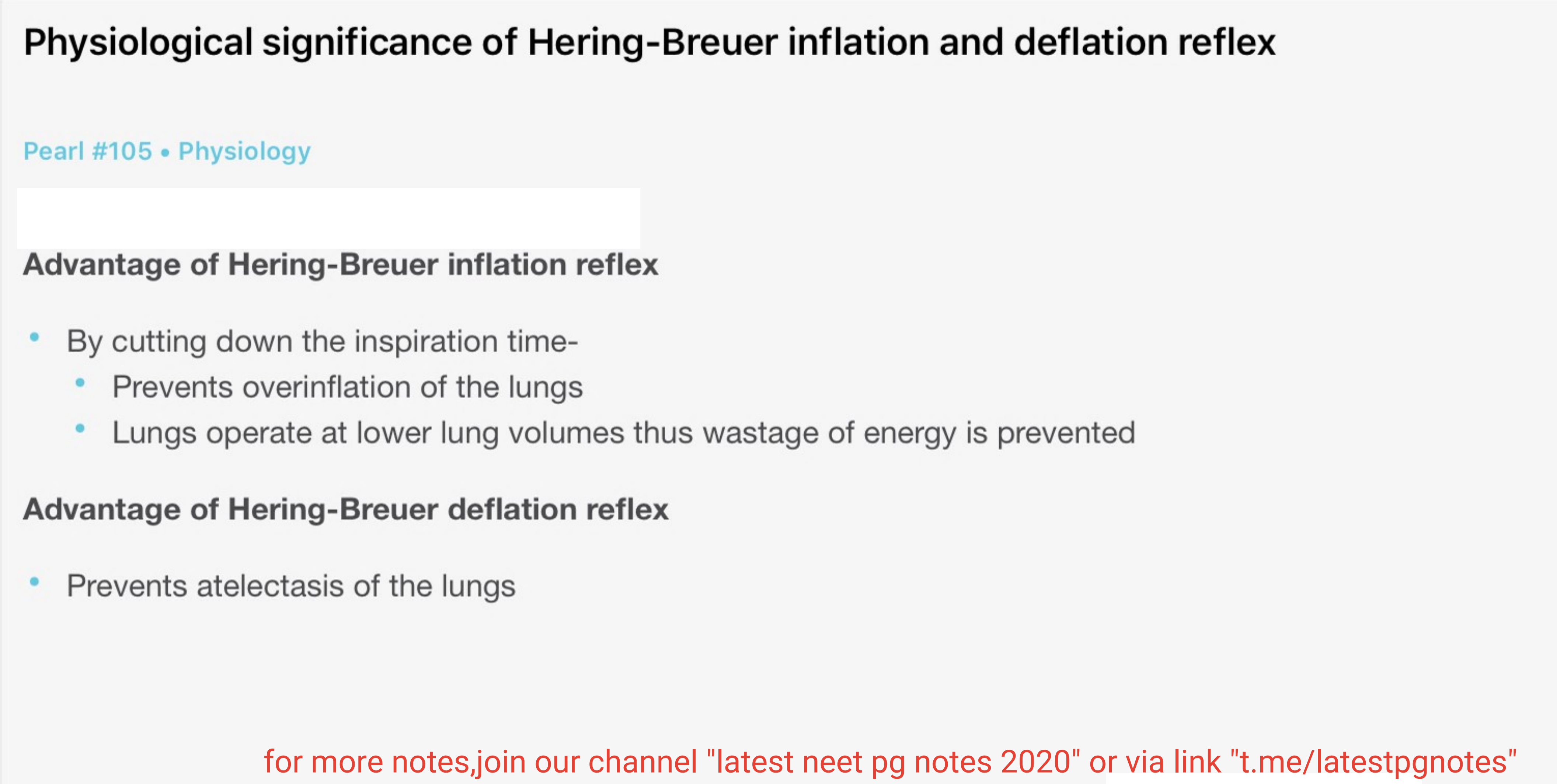


Physiological significance of Hering-Breuer inflation and deflation reflex

Pearl #105 • Physiology

Advantage of Hering-Breuer inflation reflex

- By cutting down the inspiration time-
  - Prevents overinflation of the lungs
  - Lungs operate at lower lung volumes thus wastage of energy is prevented

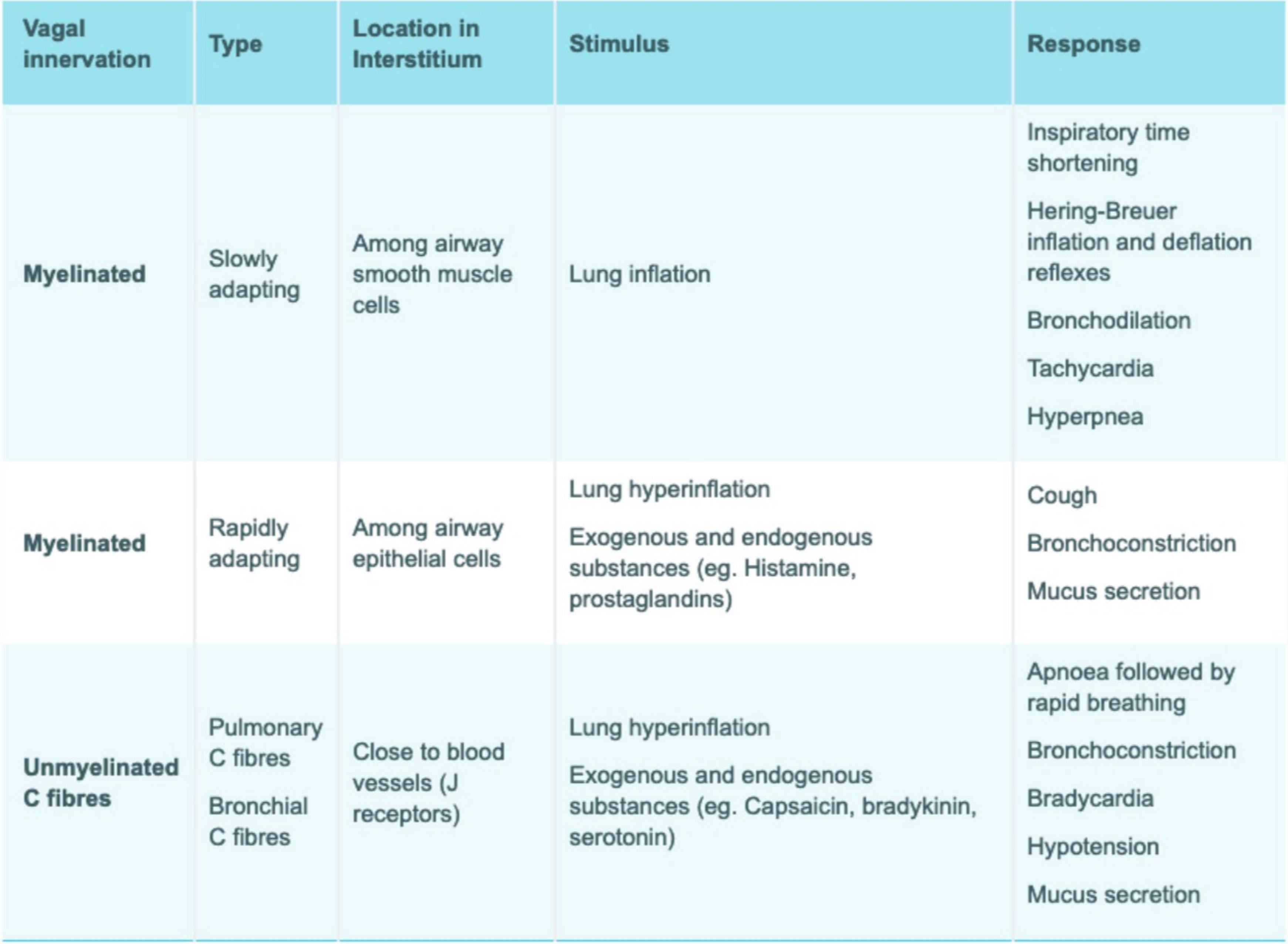
Advantage of Hering-Breuer deflation reflex

- Prevents atelectasis of the lungs

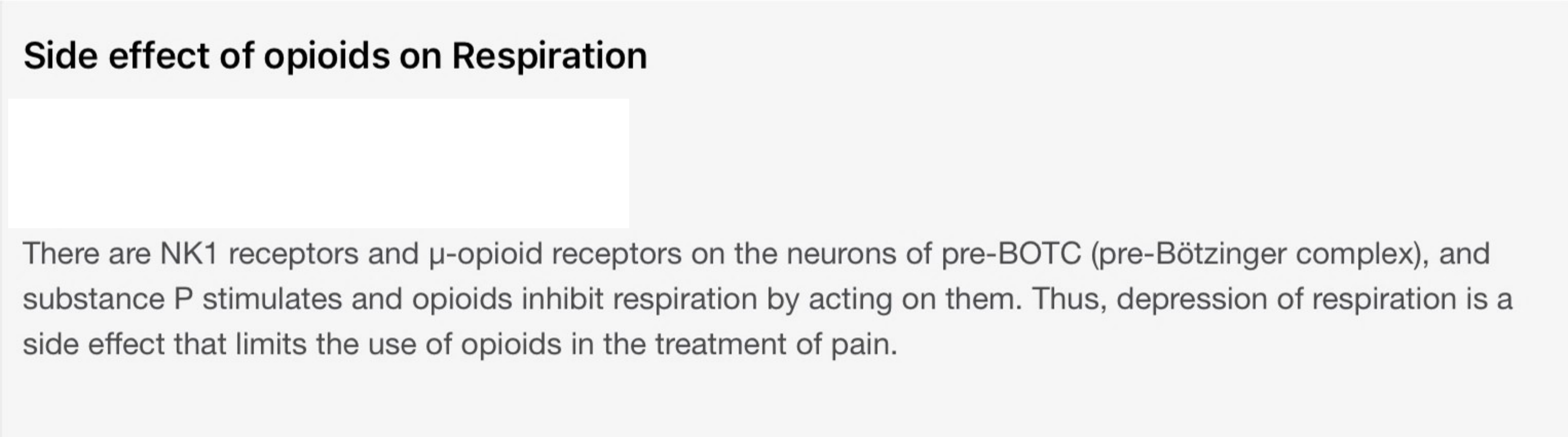
for more notes,join our channel "latest neet pg notes 2020" or via link "t.me/latestpgnotes"

Respiratory responses Mediated by Airway and Lung Receptors

Pearl #104 • Physiology

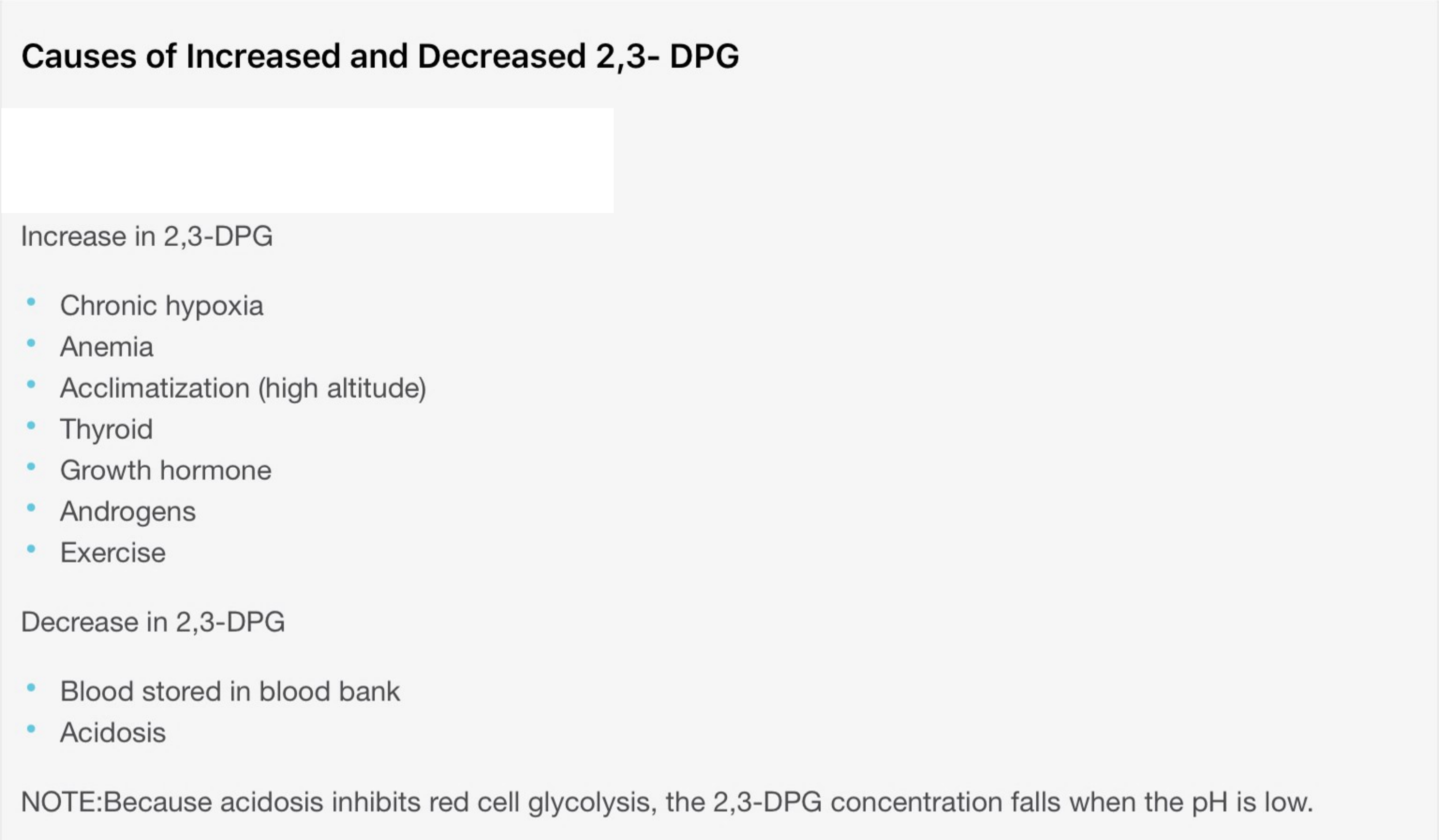


Vagal innervation	**Type**	**Location in Interstitium**	**Stimulus**	**Response**
Myelinated	Slowly adapting	Among airway smooth muscle cells	Lung inflation	Inspiratory time shortening Hering-Breuer inflation and deflation reflexes Bronchodilation Tachycardia Hyperpnea
Myelinated	Rapidly adapting	Among airway epithelial cells	Lung hyperinflation Exogenous and endogenous substances (eg. Histamine, prostaglandins)	Cough Bronchoconstriction Mucus secretion
Unmyelinated C fibres	Pulmonary C fibres Bronchial C fibres	Close to blood vessels (J receptors)	Lung hyperinflation Exogenous and endogenous substances (eg. Capsaicin, bradykinin, serotonin)	Apnoea followed by rapid breathing Bronchoconstriction Bradycardia Hypotension Mucus secretion



Side effect of opioids on Respiration

There are NK1 receptors and μ-opioid receptors on the neurons of pre-BOTC (pre-Bötzinger complex), and substance P stimulates and opioids inhibit respiration by acting on them. Thus, depression of respiration is a side effect that limits the use of opioids in the treatment of pain.



Causes of Increased and Decreased 2,3- DPG

Increase in 2,3-DPG

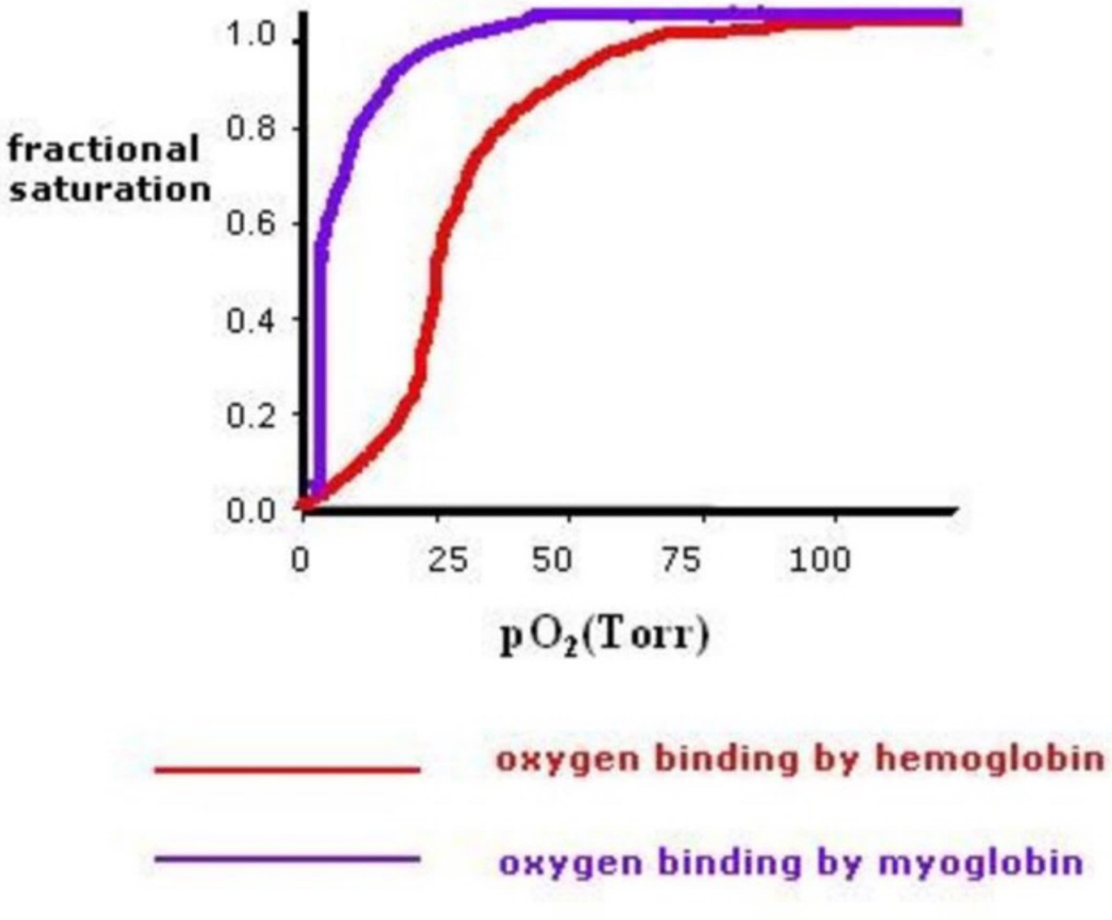
- Chronic hypoxia
- Anemia
- Acclimatization (high altitude)
- Thyroid
- Growth hormone
- Androgens
- Exercise

Decrease in 2,3-DPG

- Blood stored in blood bank
- Acidosis

NOTE:Because acidosis inhibits red cell glycolysis, the 2,3-DPG concentration falls when the pH is low.

Oxygen myoglobin dissociation curve



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- The shape of C -myoglobin dissociation curve is a rectangular hyperbola. It lies to the left of OHDC.

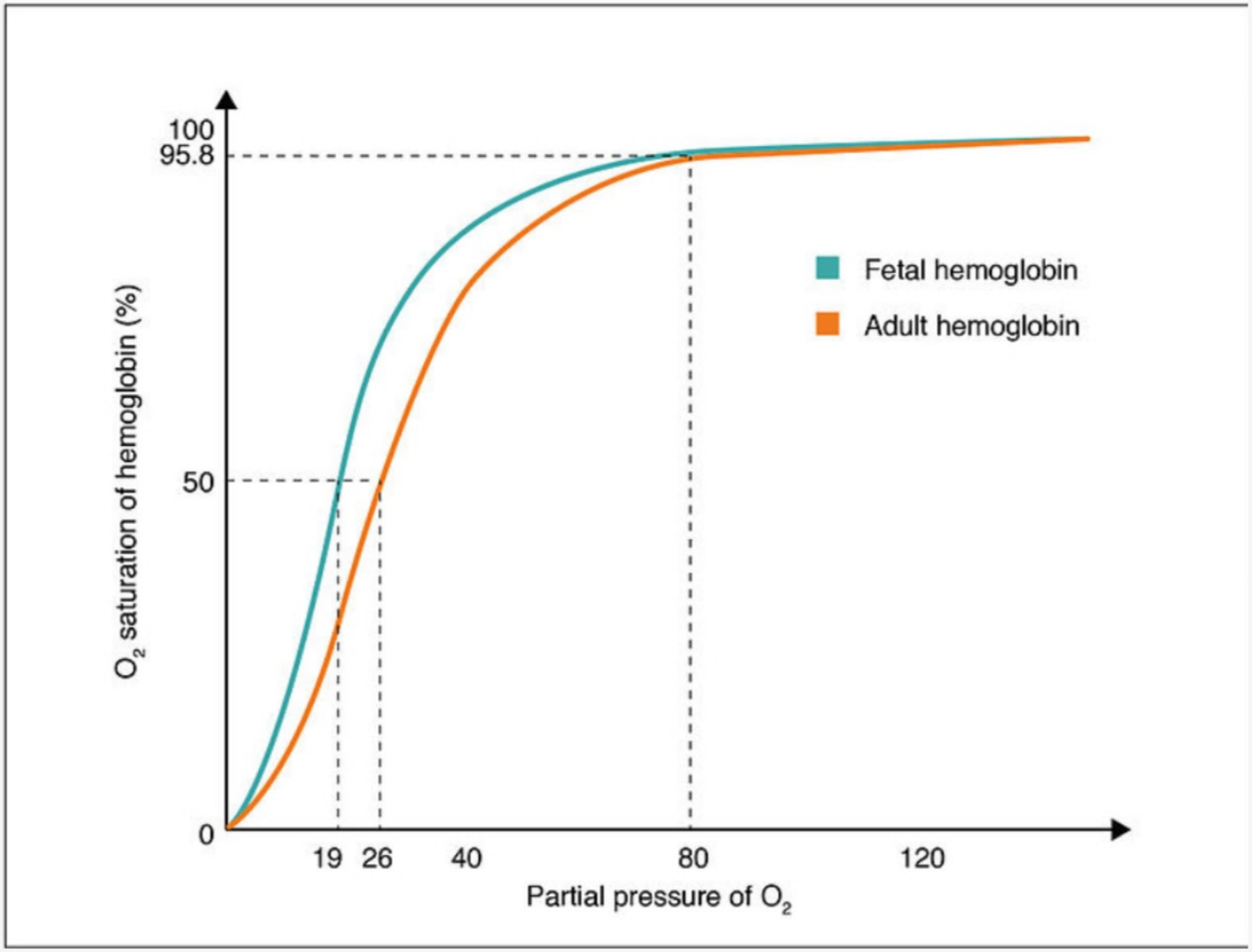
P50

Pearl #95 • Physiology

P_{50}= the partial pressure of oxygen at which Hb is 50% saturated. Its value is about 26mmHg

When the oxygen hemoglobin dissociation curve shifts to the right, P_{50} increases.

Or in other words, higher the P_{50}, lower is the affinity of Hemoglobin for O_2.



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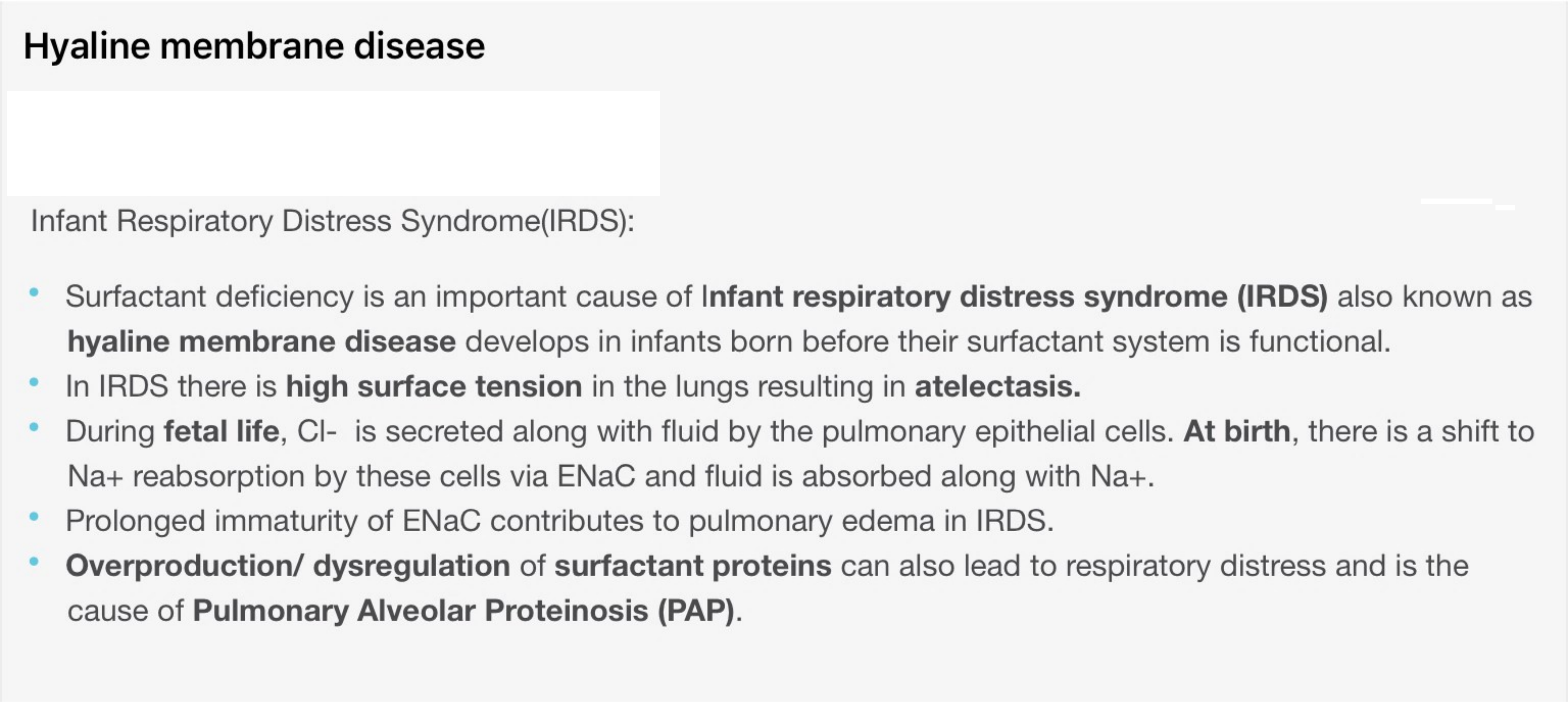
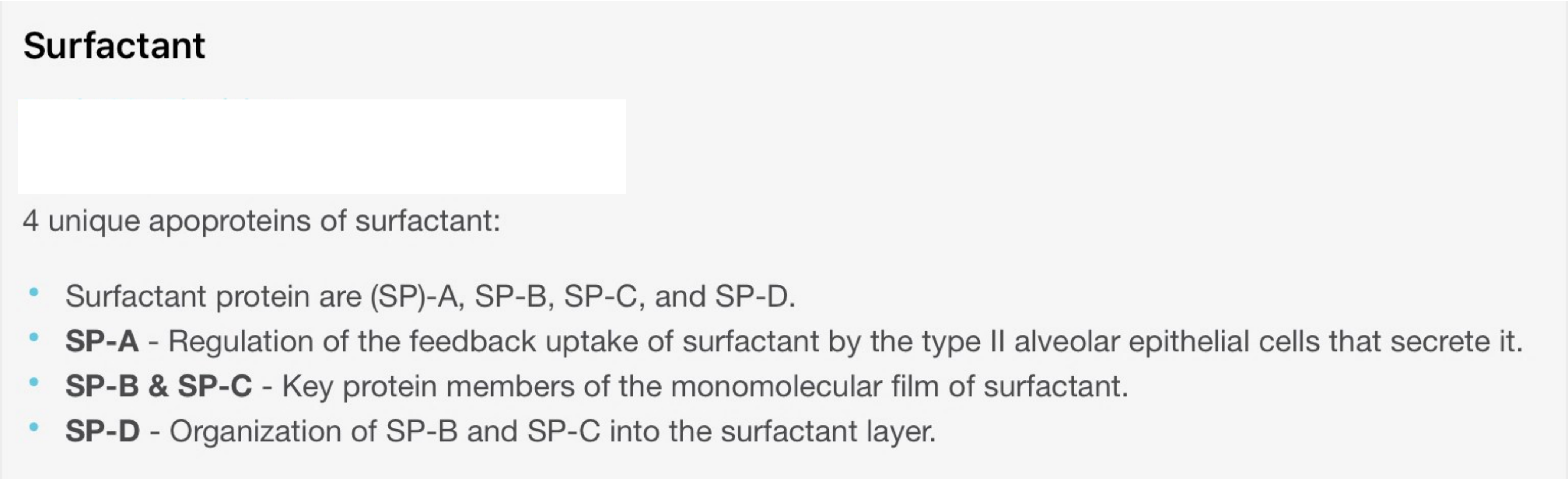


Hyaline membrane disease

Infant Respiratory Distress Syndrome(IRDS):

- Surfactant deficiency is an important cause of **Infant respiratory distress syndrome (IRDS)** also known as **hyaline membrane disease** develops in infants born before their surfactant system is functional.
- In IRDS there is **high surface tension** in the lungs resulting in **atelectasis.**
- During **fetal life**, Cl- is secreted along with fluid by the pulmonary epithelial cells. **At birth**, there is a shift to Na+ reabsorption by these cells via ENaC and fluid is absorbed along with Na+.
- Prolonged immaturity of ENaC contributes to pulmonary edema in IRDS.
- **Overproduction/ dysregulation** of **surfactant proteins** can also lead to respiratory distress and is the cause of **Pulmonary Alveolar Proteinosis (PAP)**.

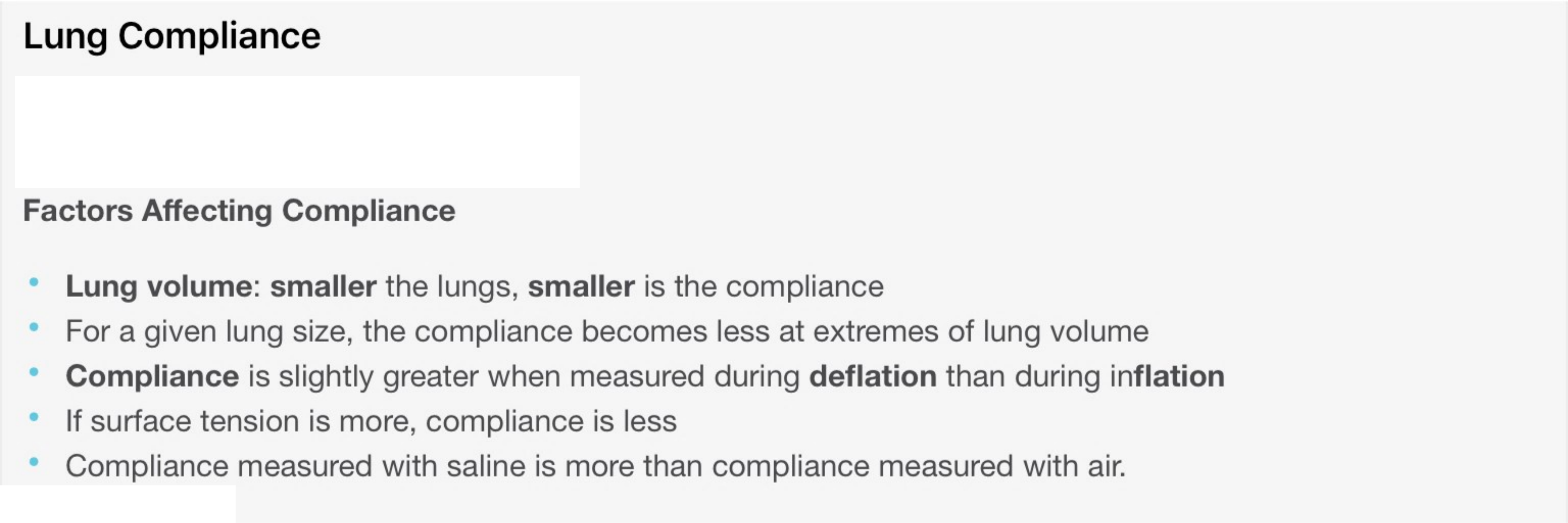


Surfactant

[redacted]

4 unique apoproteins of surfactant:

- Surfactant protein are (SP)-A, SP-B, SP-C, and SP-D.
- **SP-A** - Regulation of the feedback uptake of surfactant by the type II alveolar epithelial cells that secrete it.
- **SP-B & SP-C** - Key protein members of the monomolecular film of surfactant.
- **SP-D** - Organization of SP-B and SP-C into the surfactant layer.



Lung Compliance

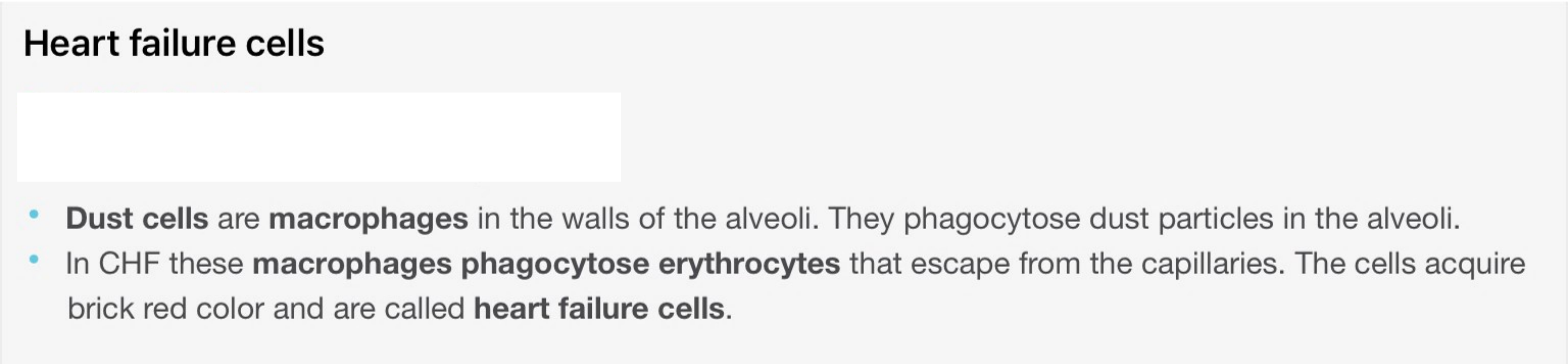
Factors Affecting Compliance

- **Lung volume**: **smaller** the lungs, **smaller** is the compliance
- For a given lung size, the compliance becomes less at extremes of lung volume
- **Compliance** is slightly greater when measured during **deflation** than during in**flation**
- If surface tension is more, compliance is less
- Compliance measured with saline is more than compliance measured with air.

Biologically active substances metabolized by lungs

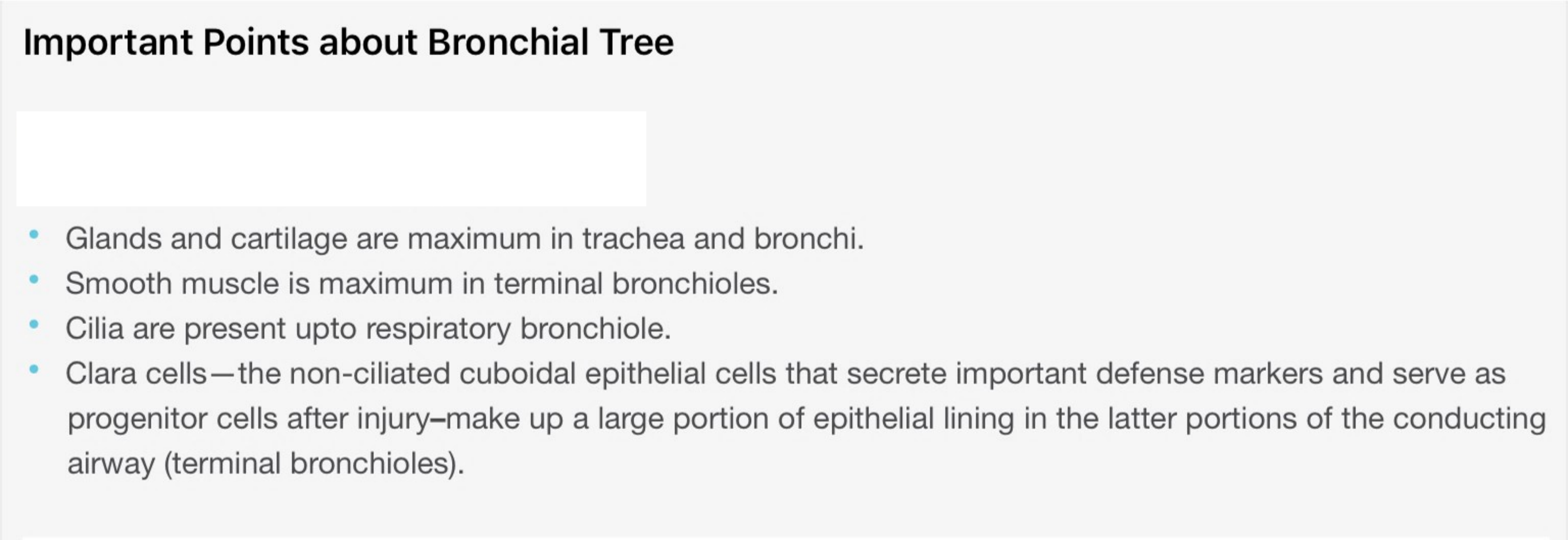
Pearl #86 • Physiology

Synthesized and used in the lungs
Surfactant
Synthesized or stored and released into the blood
Prostaglandins
Histamine
Kallikrein
Partially removed from the blood
Prostaglandins
Bradykinin
Adenine nucleotides
Serotonin
Norepinephrine
Acetylcholine
Activated in the lungs
Angiotensin I → Angiotensin II



Heart failure cells

- **Dust cells** are **macrophages** in the walls of the alveoli. They phagocytose dust particles in the alveoli.
- In CHF these **macrophages phagocytose erythrocytes** that escape from the capillaries. The cells acquire brick red color and are called **heart failure cells**.



Important Points about Bronchial Tree

- Glands and cartilage are maximum in trachea and bronchi.
- Smooth muscle is maximum in terminal bronchioles.
- Cilia are present upto respiratory bronchiole.
- Clara cells—the non-ciliated cuboidal epithelial cells that secrete important defense markers and serve as progenitor cells after injury–make up a large portion of epithelial lining in the latter portions of the conducting airway (terminal bronchioles).

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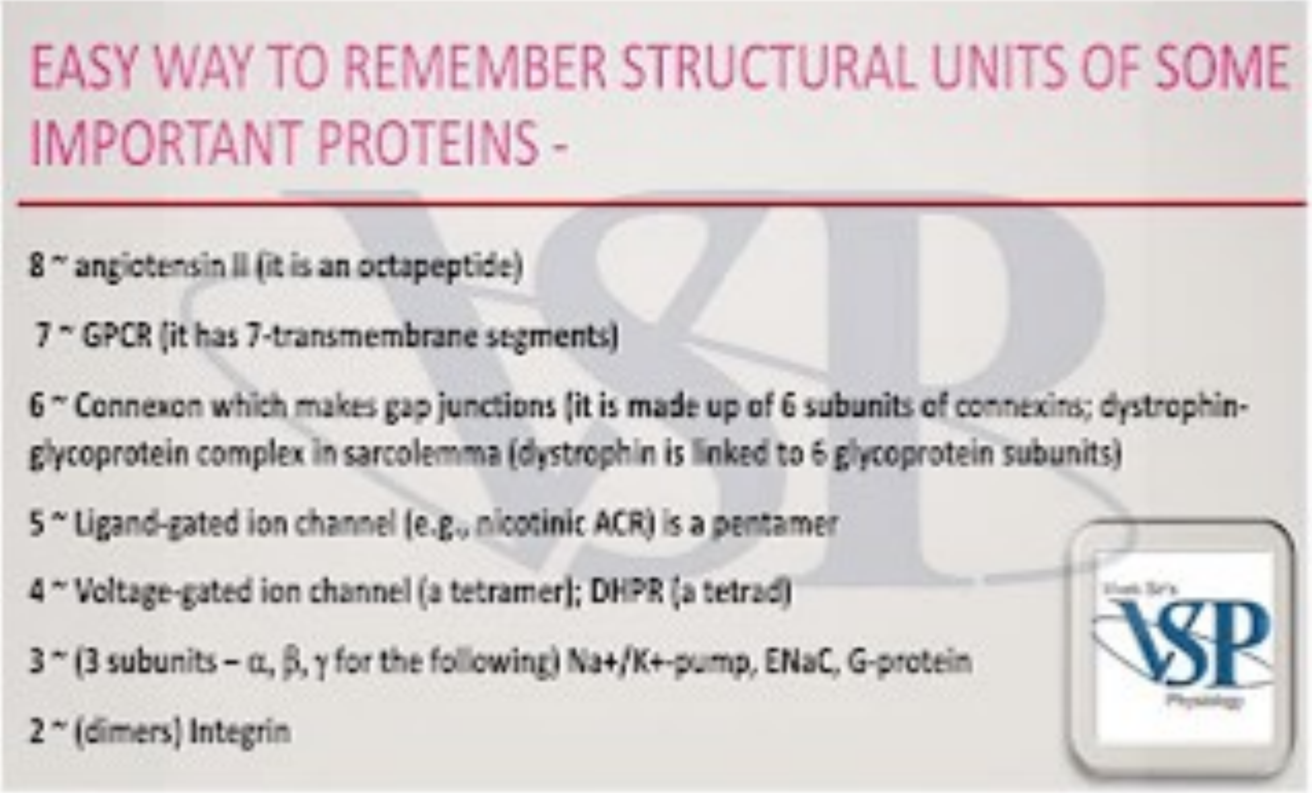
Factual Capsule.



EASY WAY TO REMEMBER STRUCTURAL UNITS OF SOME IMPORTANT PROTEINS -

8 ~ angiotensin II (it is an octapeptide)

7 ~ GPCR (it has 7-transmembrane segments)

6 ~ Connexon which makes gap junctions (it is made up of 6 subunits of connexins; dystrophin-glycoprotein complex in sarcolemma (dystrophin is linked to 6 glycoprotein subunits)

5 ~ Ligand-gated ion channel (e.g., nicotinic ACR) is a pentamer

4 ~ Voltage-gated ion channel (a tetramer); DHPR (a tetrad)

3 ~ (3 subunits – α, β, γ for the following) Na+/K+-pump, ENaC, G-protein

2 ~ (dimers) Integrin

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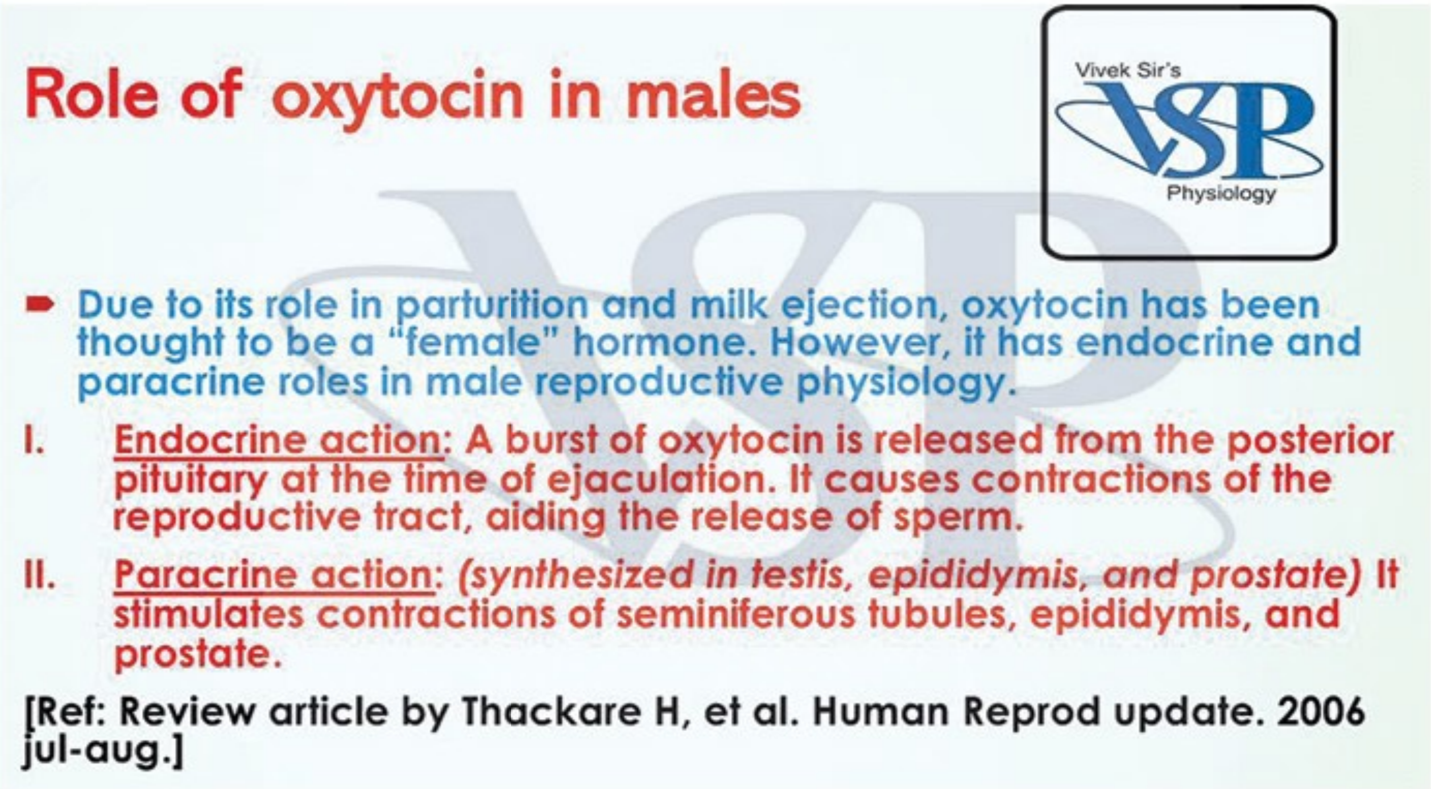

Role of oxytocin in males

- Due to its role in parturition and milk ejection, oxytocin has been thought to be a "female" hormone. However, it has endocrine and paracrine roles in male reproductive physiology.

I. Endocrine action: A burst of oxytocin is released from the posterior pituitary at the time of ejaculation. It causes contractions of the reproductive tract, aiding the release of sperm.

II. Paracrine action: *(synthesized in testis, epididymis, and prostate)* It stimulates contractions of seminiferous tubules, epididymis, and prostate.

[Ref: Review article by Thackare H, et al. Human Reprod update. 2006 jul-aug.]

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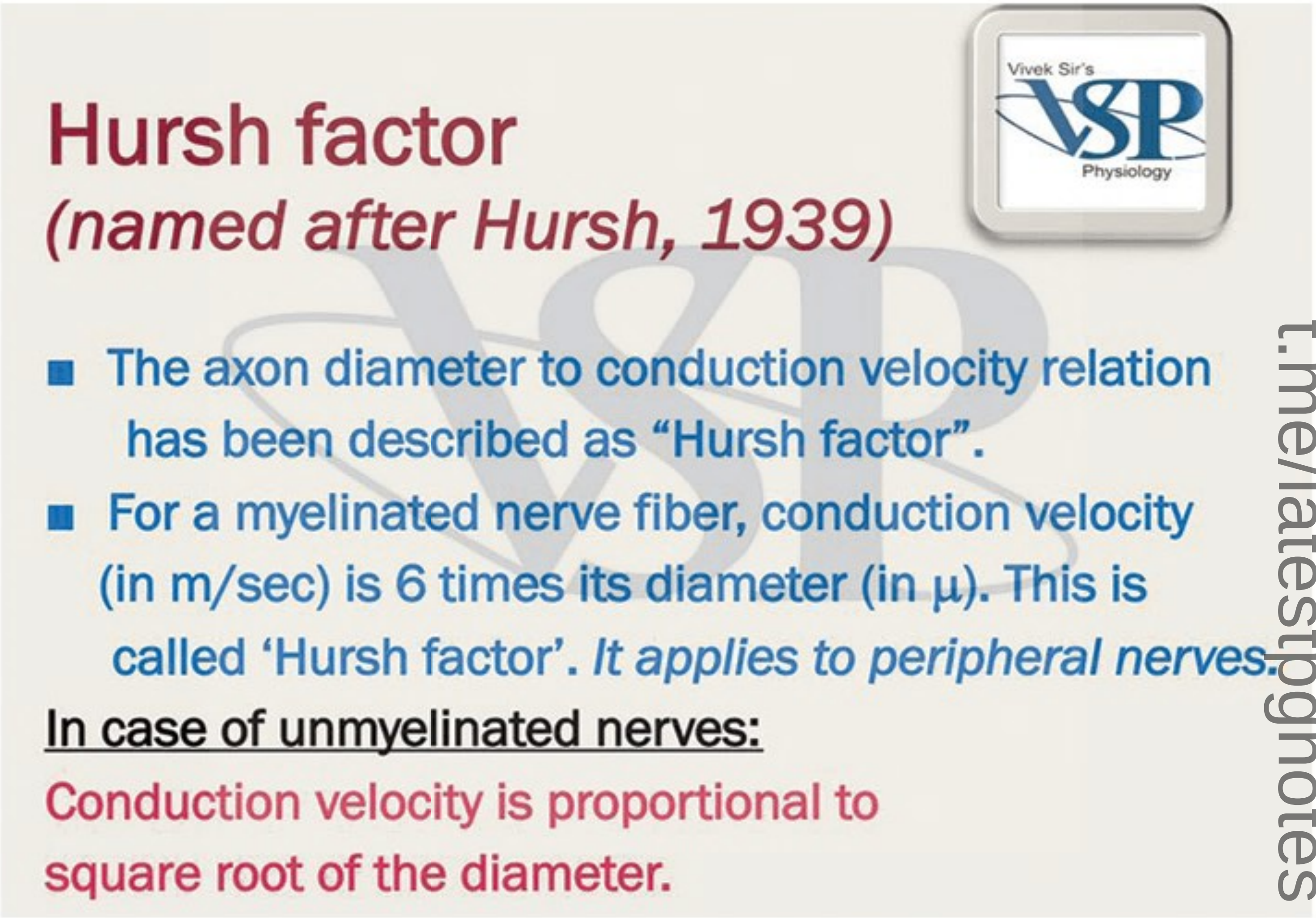

Hursh factor

(named after Hursh, 1939)

- The axon diameter to conduction velocity relation has been described as “Hursh factor”.
- For a myelinated nerve fiber, conduction velocity (in m/sec) is 6 times its diameter (in μ). This is called ‘Hursh factor’. *It applies to peripheral nerves.*

In case of unmyelinated nerves:

Conduction velocity is proportional to square root of the diameter.

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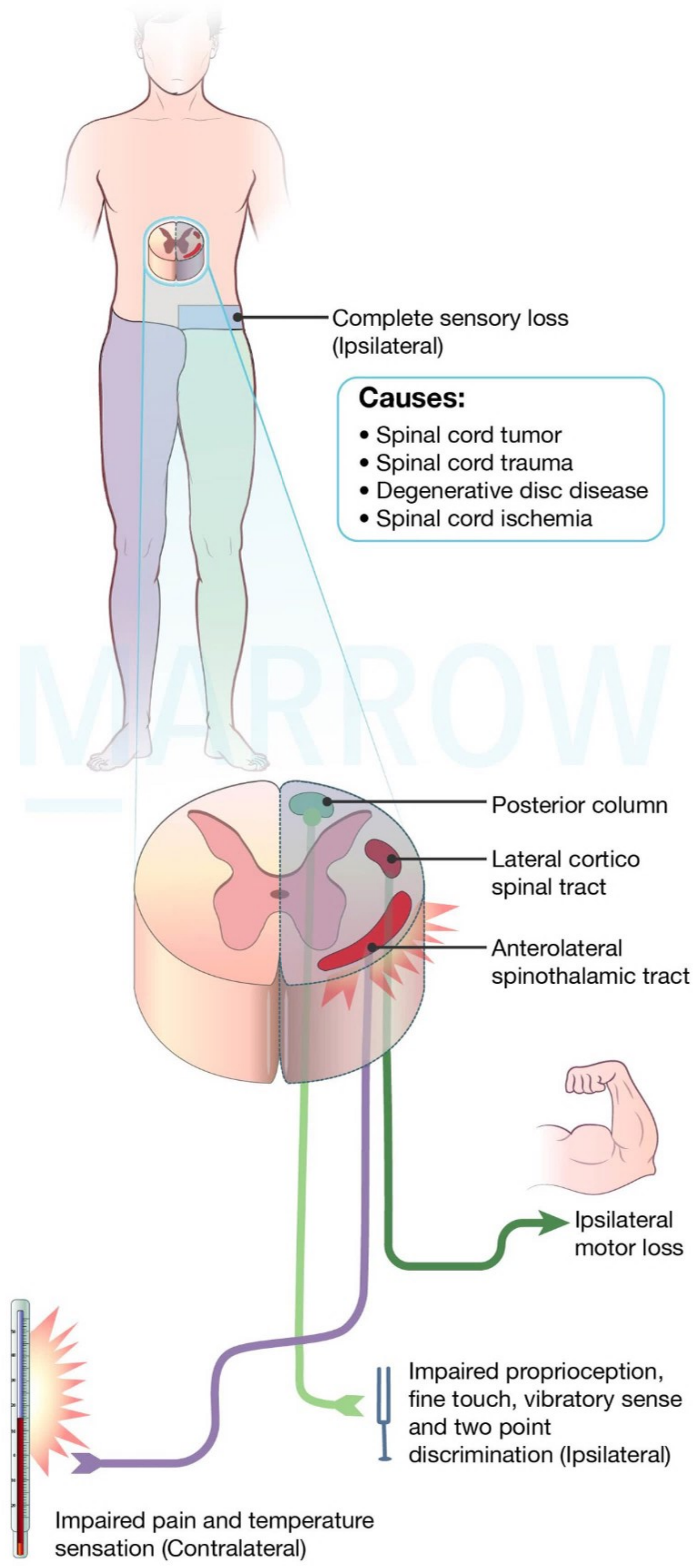
Brown-Sequard syndrome
(Hemisection of spinal cord)


Complete sensory loss
(Ipsilateral)
Posterior column
Lateral cortico spinal tract
Anterolateral spinothalamic tract
Ipsilateral motor loss
Impaired proprioception, fine touch, vibratory sense and two point discrimination (Ipsilateral)
Impaired pain and temperature sensation (Contralateral)

Causes:
- Spinal cord tumor
- Spinal cord trauma
- Degenerative disc disease
- Spinal cord ischemia

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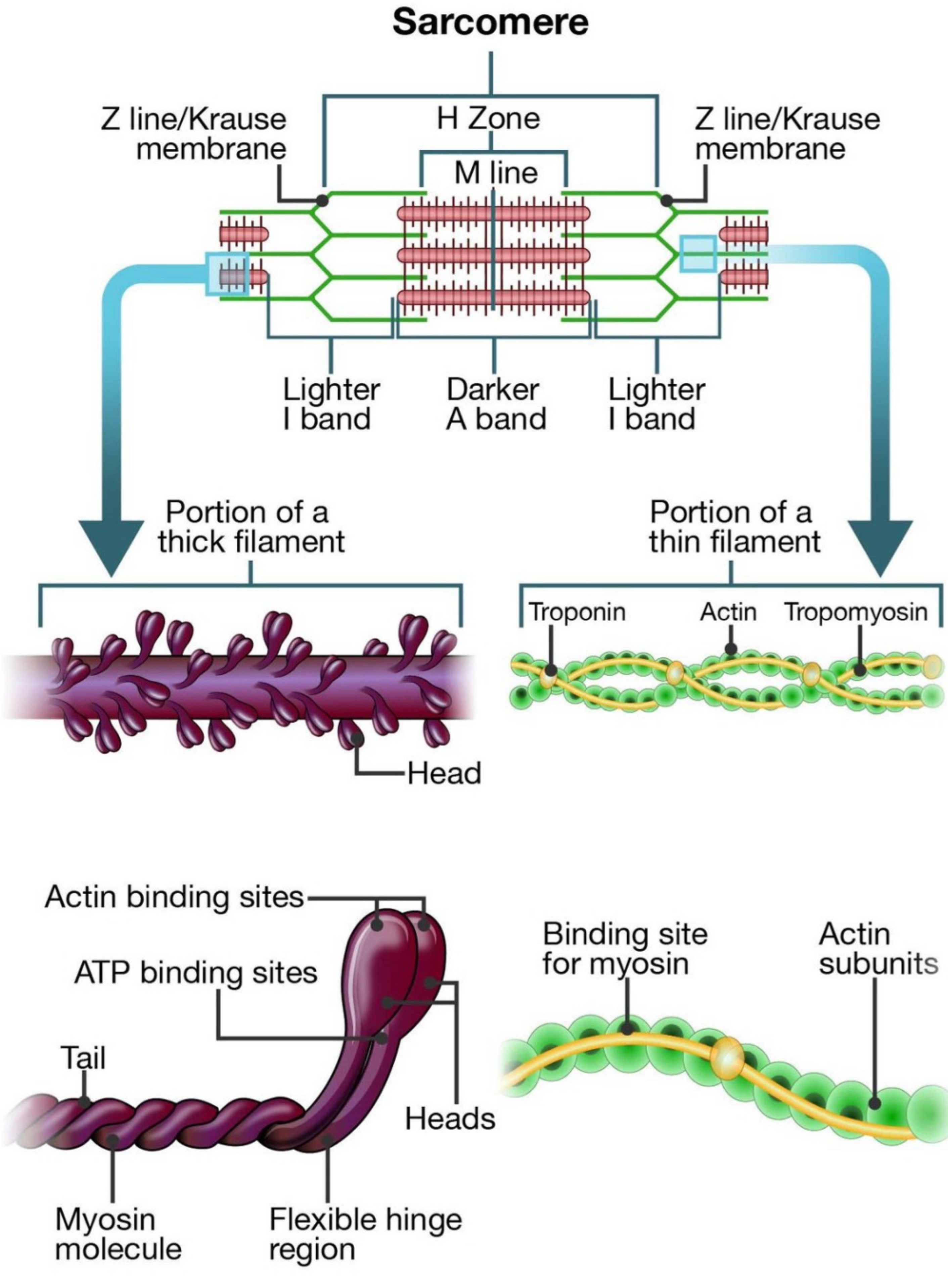
Sarcomere
Z line/Krause membrane
H Zone
Z line/Krause membrane
M line
Lighter I band
Darker A band
Lighter I band
Portion of a thick filament
Portion of a thin filament
Troponin
Actin
Tropomyosin
Head
Actin binding sites
ATP binding sites
Tail
Heads
Myosin molecule
Flexible hinge region
Binding site for myosin
Actin subunits

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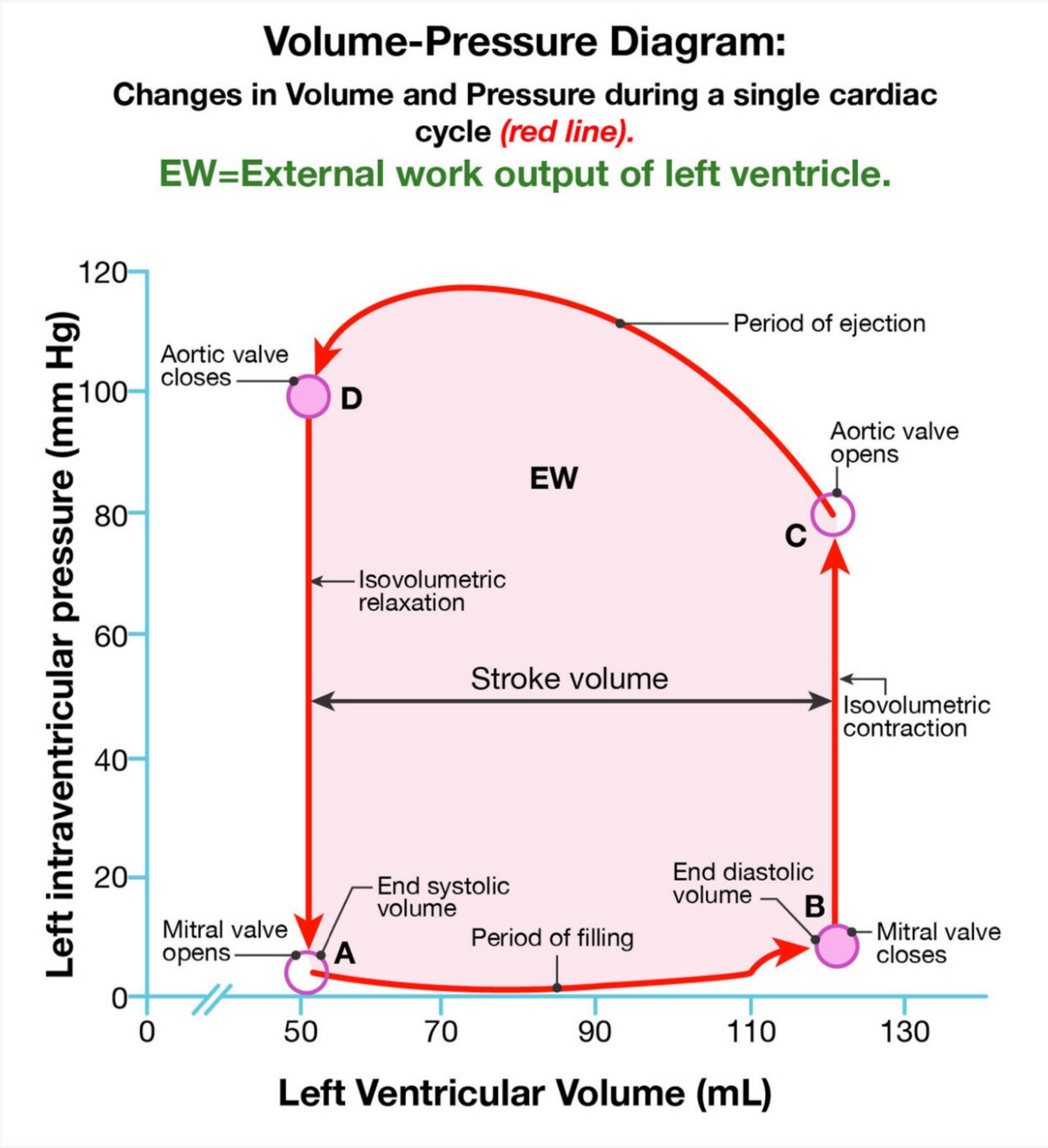

Volume-Pressure Diagram:

Changes in Volume and Pressure during a single cardiac cycle *(red line).*

EW=External work output of left ventricle.

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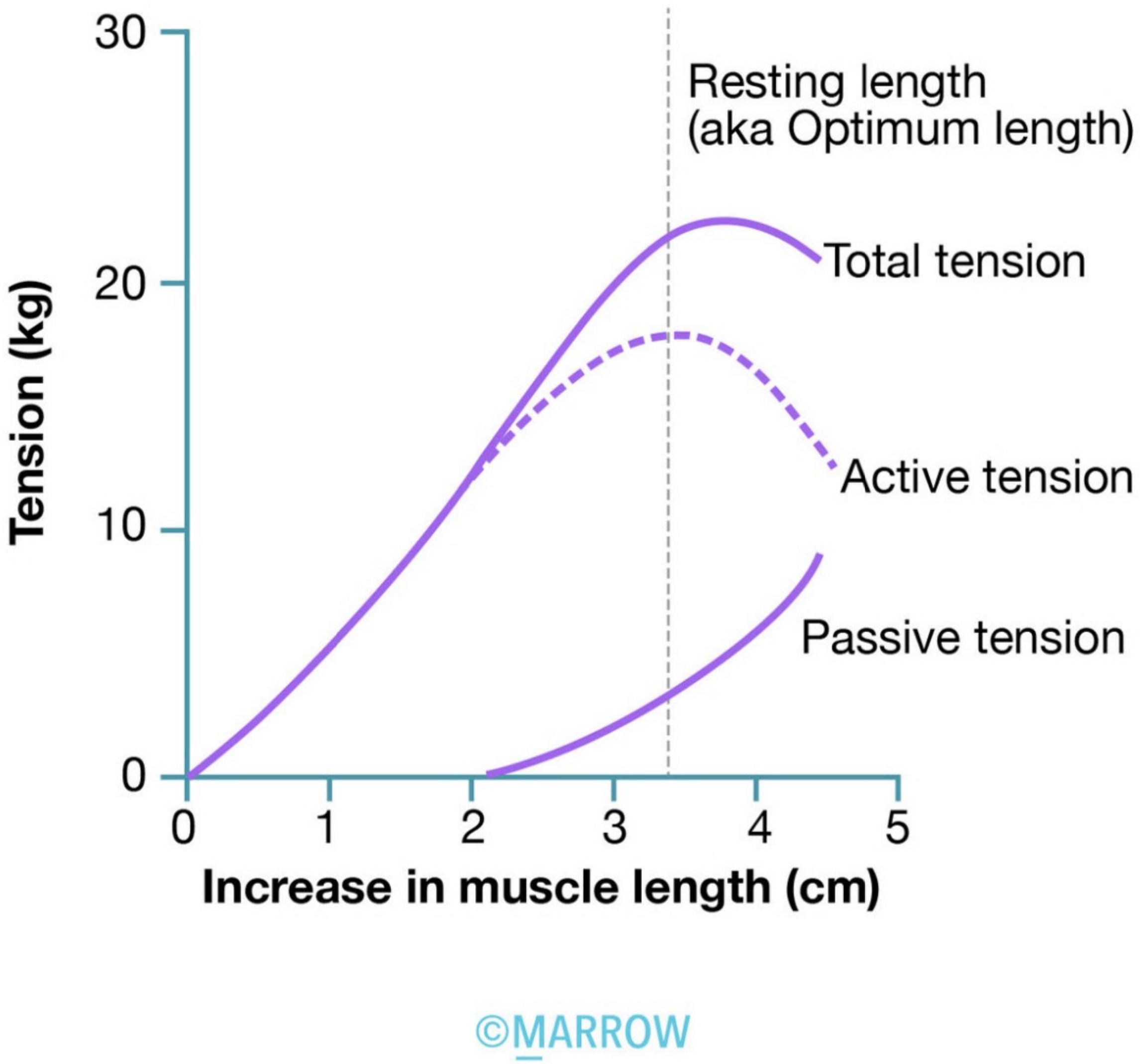
Phase I: Period of filling (between A and B)

Phase II: Period of isovolumic contraction (between B and C)

Phase III: Period of ejection (between C and D)

Phase IV: Period of isovolumic relaxation (between D and A)



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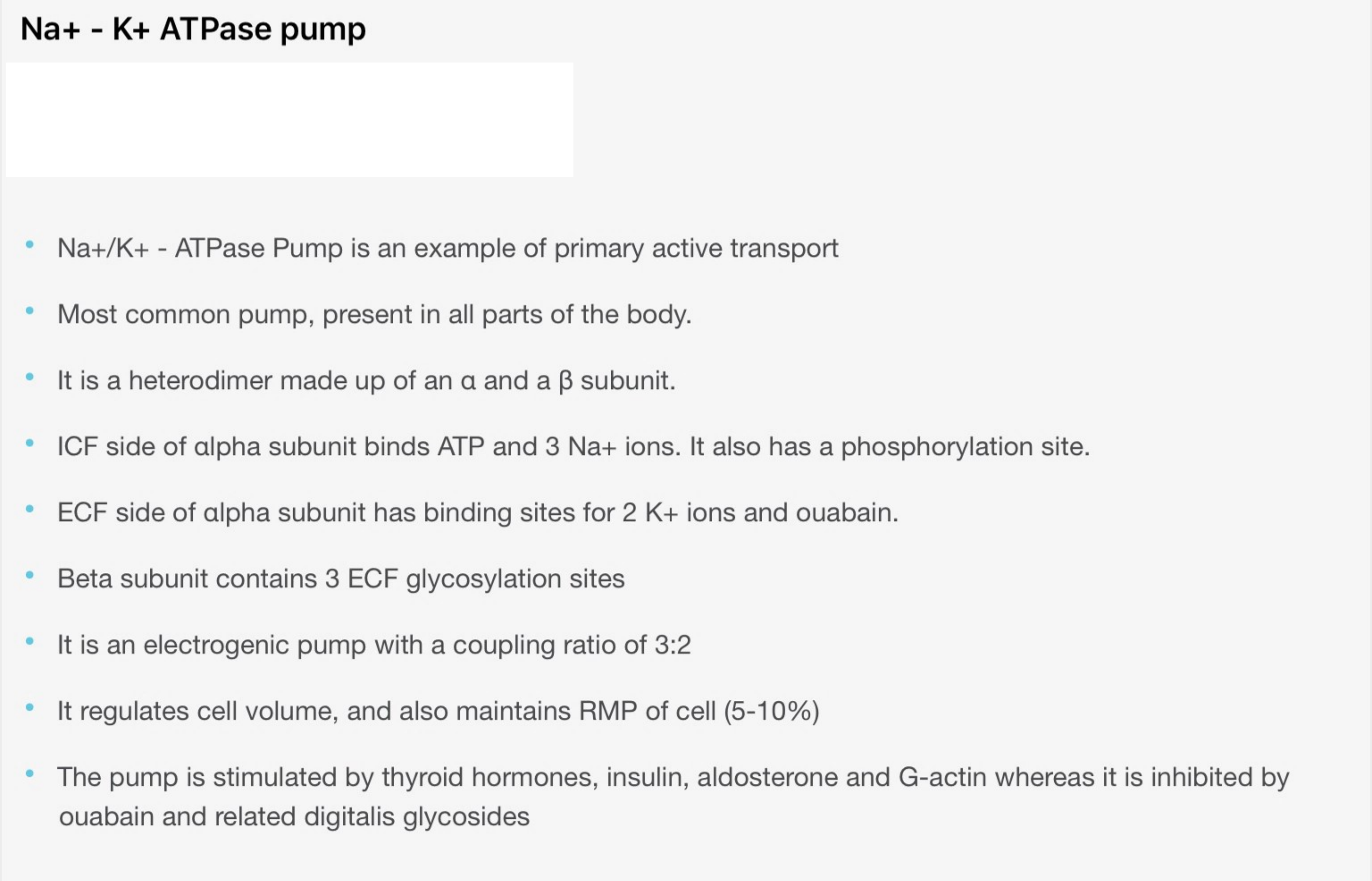
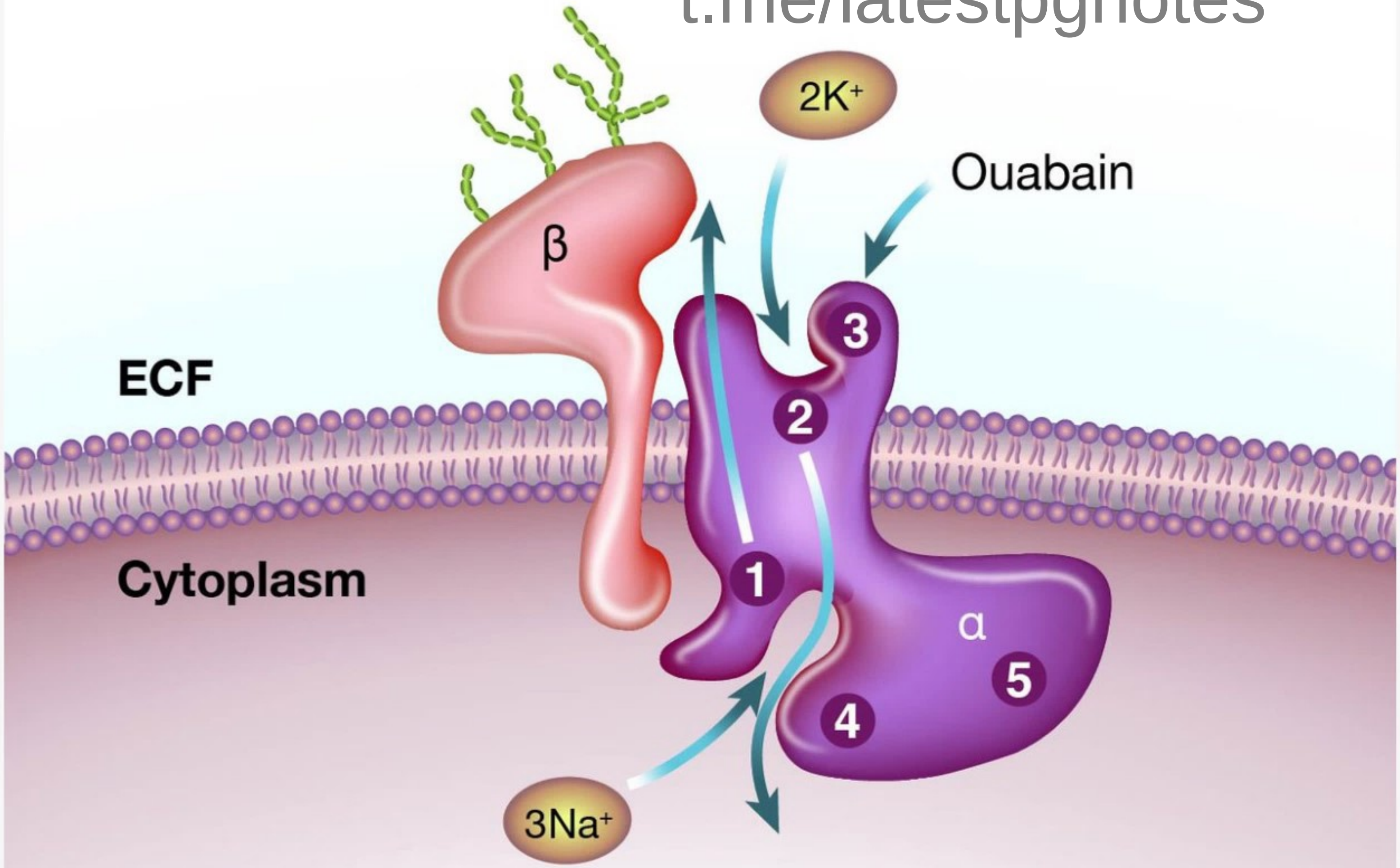
- The passive tension curve measures the tension exerted by this skeletal muscle at each length when it is not stimulated.
- The total tension curve represents the tension developed when the muscle contracts isometrically in response to a maximal stimulus.
- The active tension is the difference between the total tension and passive tension



Na+ - K+ ATPase pump

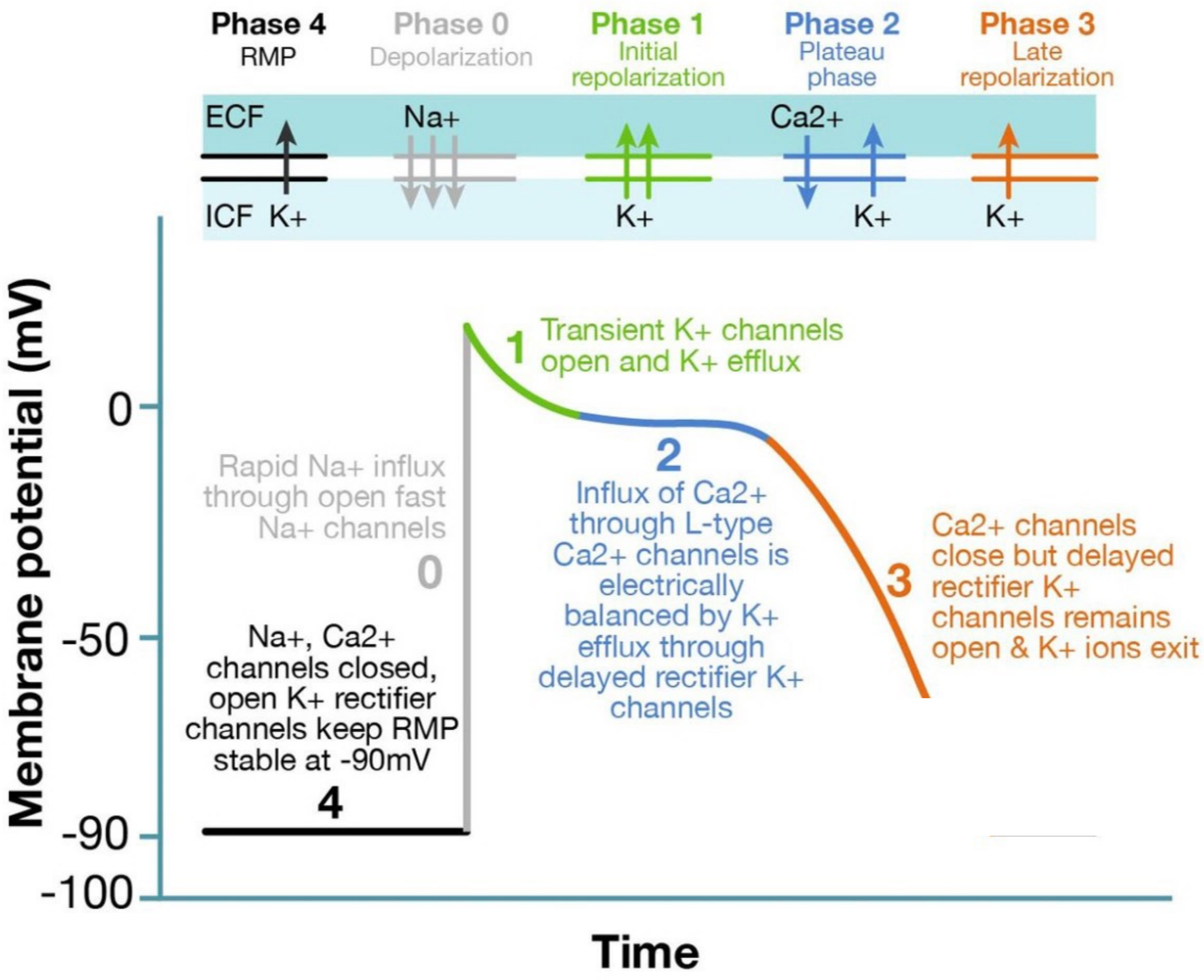
- Na+/K+ - ATPase Pump is an example of primary active transport
- Most common pump, present in all parts of the body.
- It is a heterodimer made up of an α and a β subunit.
- ICF side of alpha subunit binds ATP and 3 Na+ ions. It also has a phosphorylation site.
- ECF side of alpha subunit has binding sites for 2 K+ ions and ouabain.
- Beta subunit contains 3 ECF glycosylation sites
- It is an electrogenic pump with a coupling ratio of 3:2
- It regulates cell volume, and also maintains RMP of cell (5-10%)
- The pump is stimulated by thyroid hormones, insulin, aldosterone and G-actin whereas it is inhibited by ouabain and related digitalis glycosides



The intracellular portion of the alpha subunit has Na+ binding site**(1)**, a phosphorylation site**(4)**, and an ATP binding site**(5)**, the extracellular portion of the K+ binding site**(2)**, and the ouabain binding site**(3)**.

Cardiac action potential

Pearl #2341 • Physiology



Phase 4
RMP
Phase 0
Depolarization
Phase 1
Initial repolarization
Phase 2
Plateau phase
Phase 3
Late repolarization
ECF
ICF
K+
Na+
K+
Ca2+
K+
K+
Membrane potential (mV)
0
-50
-90
-100
Time
1
Transient K+ channels open and K+ efflux
2
Influx of Ca2+ through L-type Ca2+ channels is electrically balanced by K+ efflux through delayed rectifier K+ channels
3
Ca2+ channels close but delayed rectifier K+ channels remains open & K+ ions exit
Rapid Na+ influx through open fast Na+ channels
0
Na+, Ca2+ channels closed, open K+ rectifier channels keep RMP stable at -90mV
4

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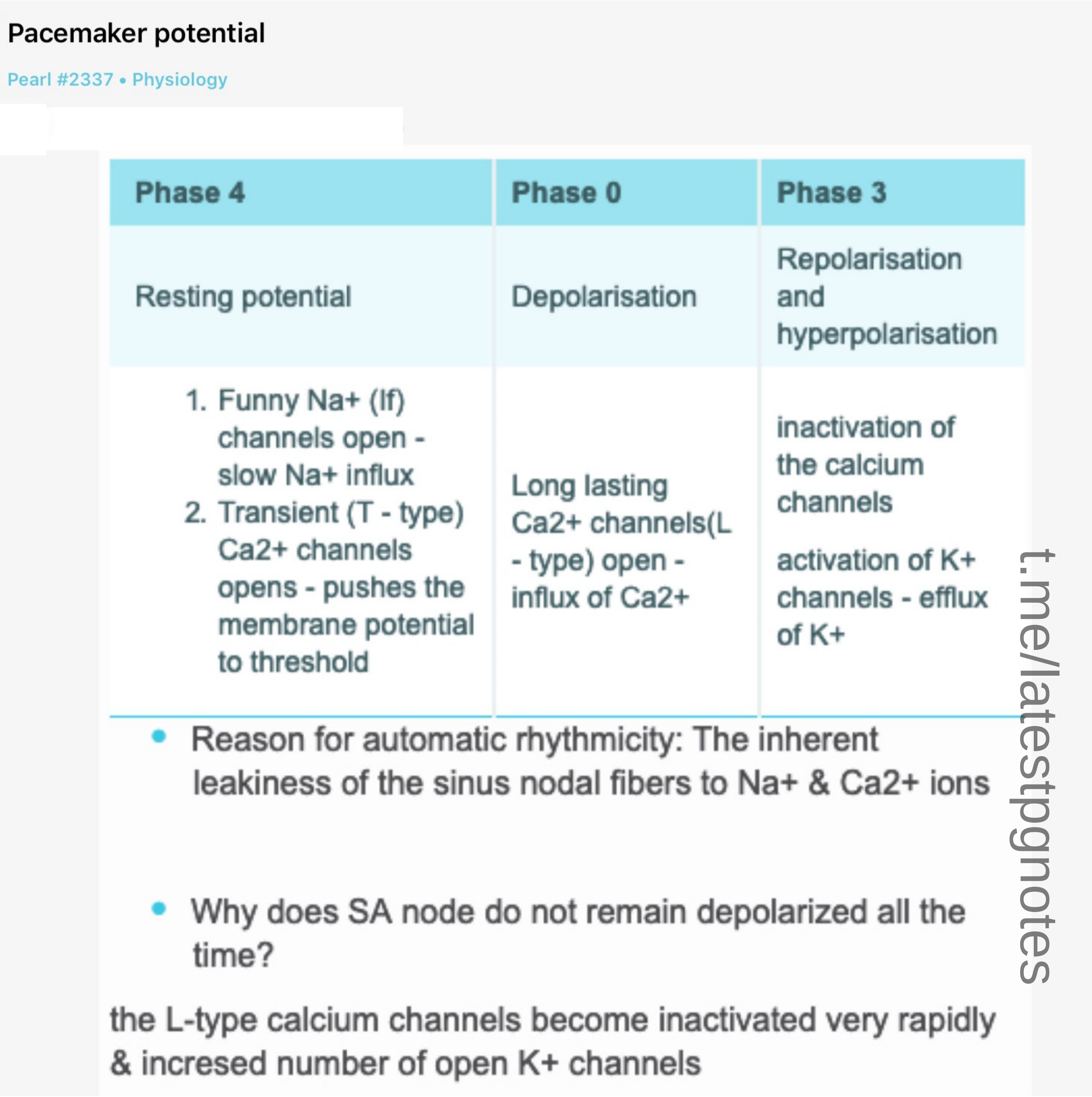


Pacemaker potential

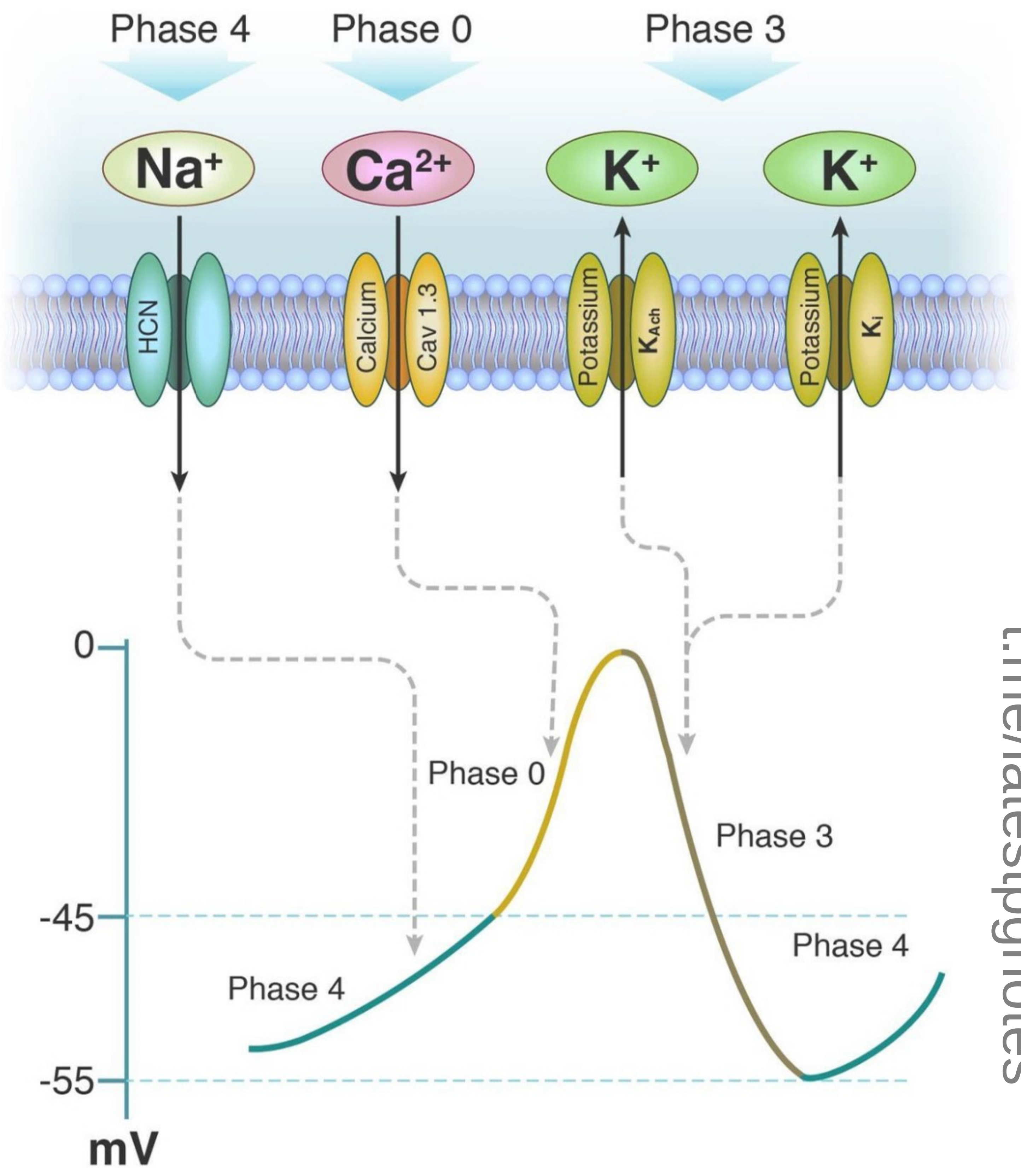
Pearl #2337 • Physiology

Phase 4	Phase 0	Phase 3
Resting potential	Depolarisation	Repolarisation and hyperpolarisation
1. Funny Na+ (If) channels open - slow Na+ influx 2. Transient (T - type) Ca2+ channels opens - pushes the membrane potential to threshold	Long lasting Ca2+ channels(L - type) open - influx of Ca2+	inactivation of the calcium channels activation of K+ channels - efflux of K+

- Reason for automatic rhythmicity: The inherent leakiness of the sinus nodal fibers to Na+ & Ca2+ ions

- Why does SA node do not remain depolarized all the time?

the L-type calcium channels become inactivated very rapidly & incresed number of open K+ channels


Phase 4
Phase 0
Phase 3
Na+
Ca2+
K+
K+
HCN
Calcium
Cav 1.3
Potassium
KAch
Potassium
Ki
0
-45
-55
mV
Phase 0
Phase 3
Phase 4
Phase 4

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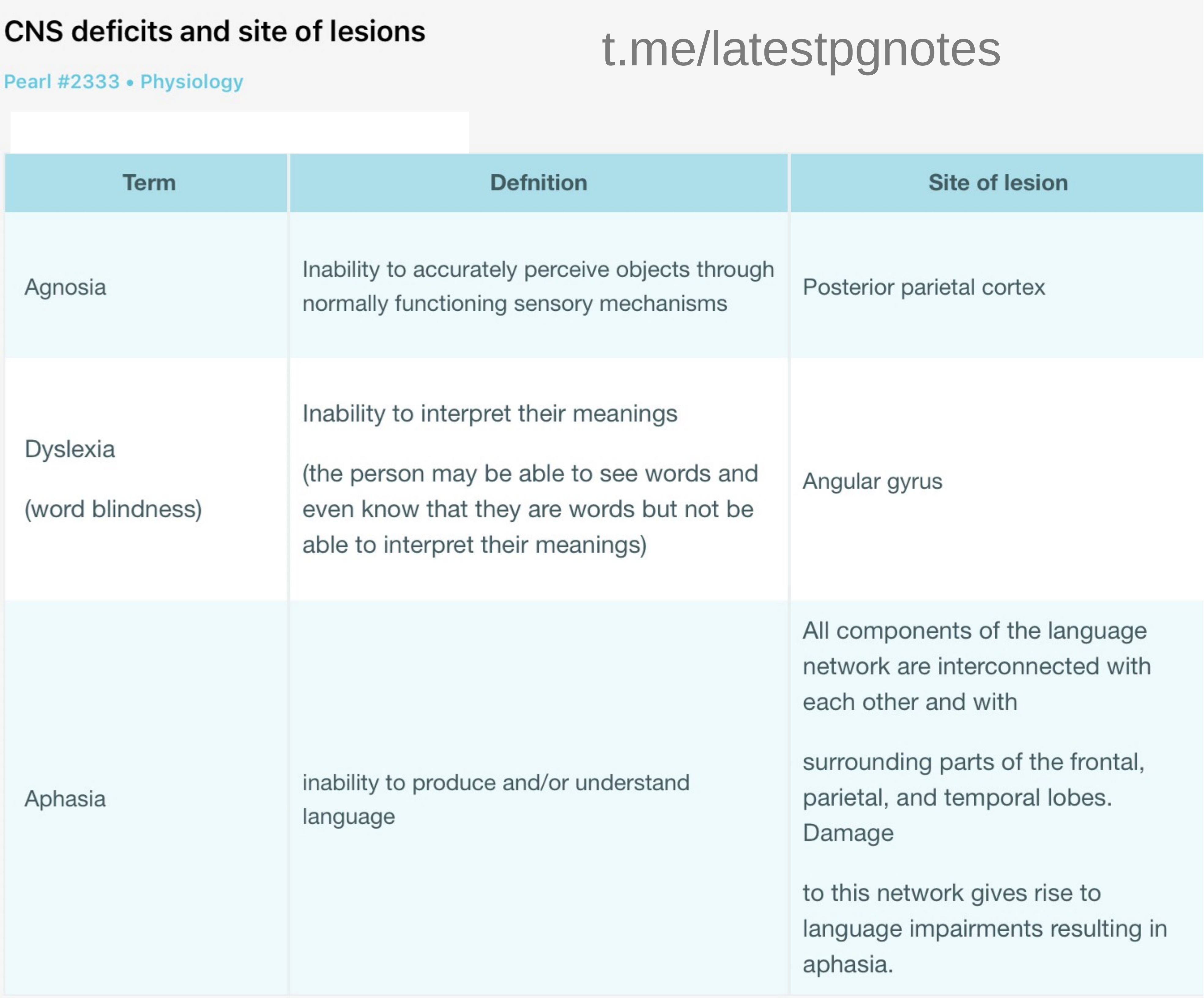
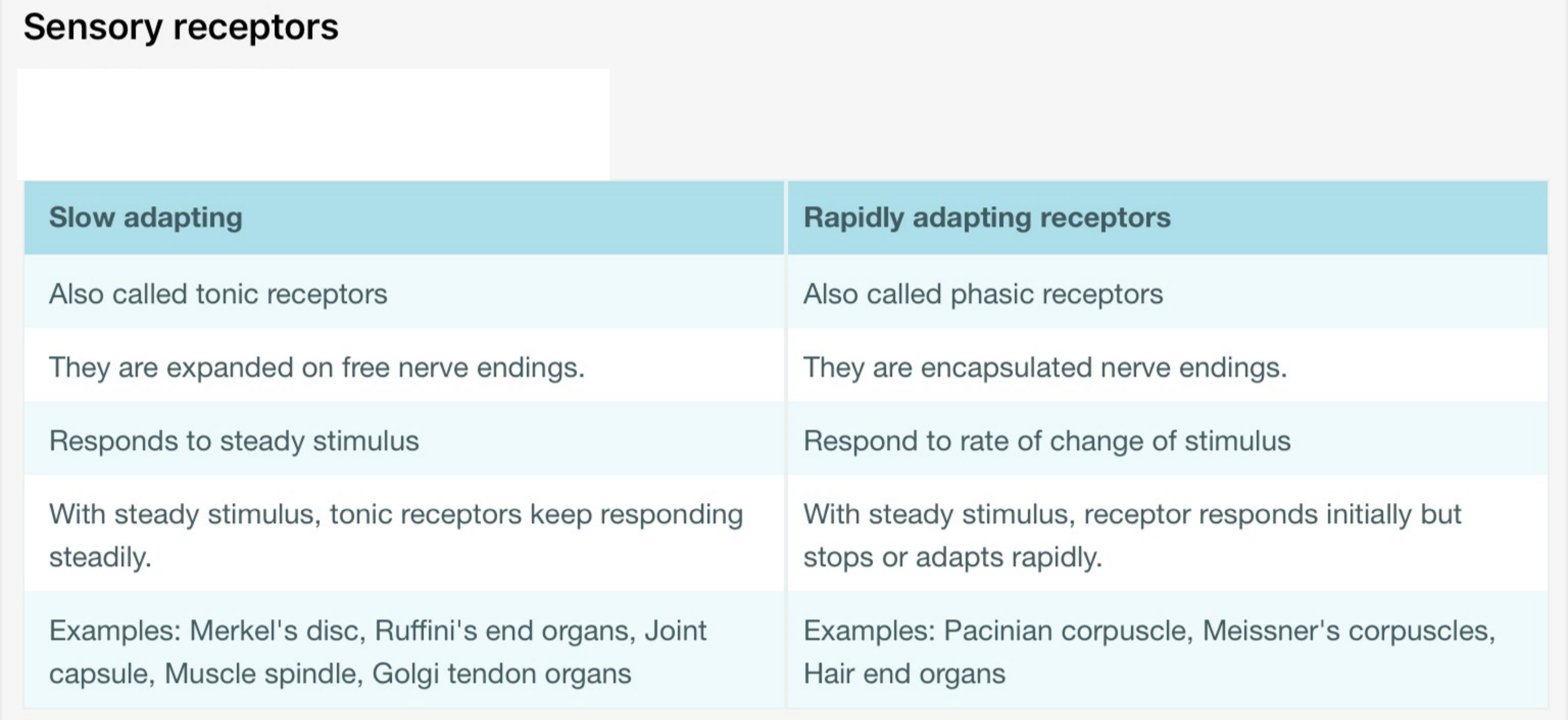


CNS deficits and site of lesions

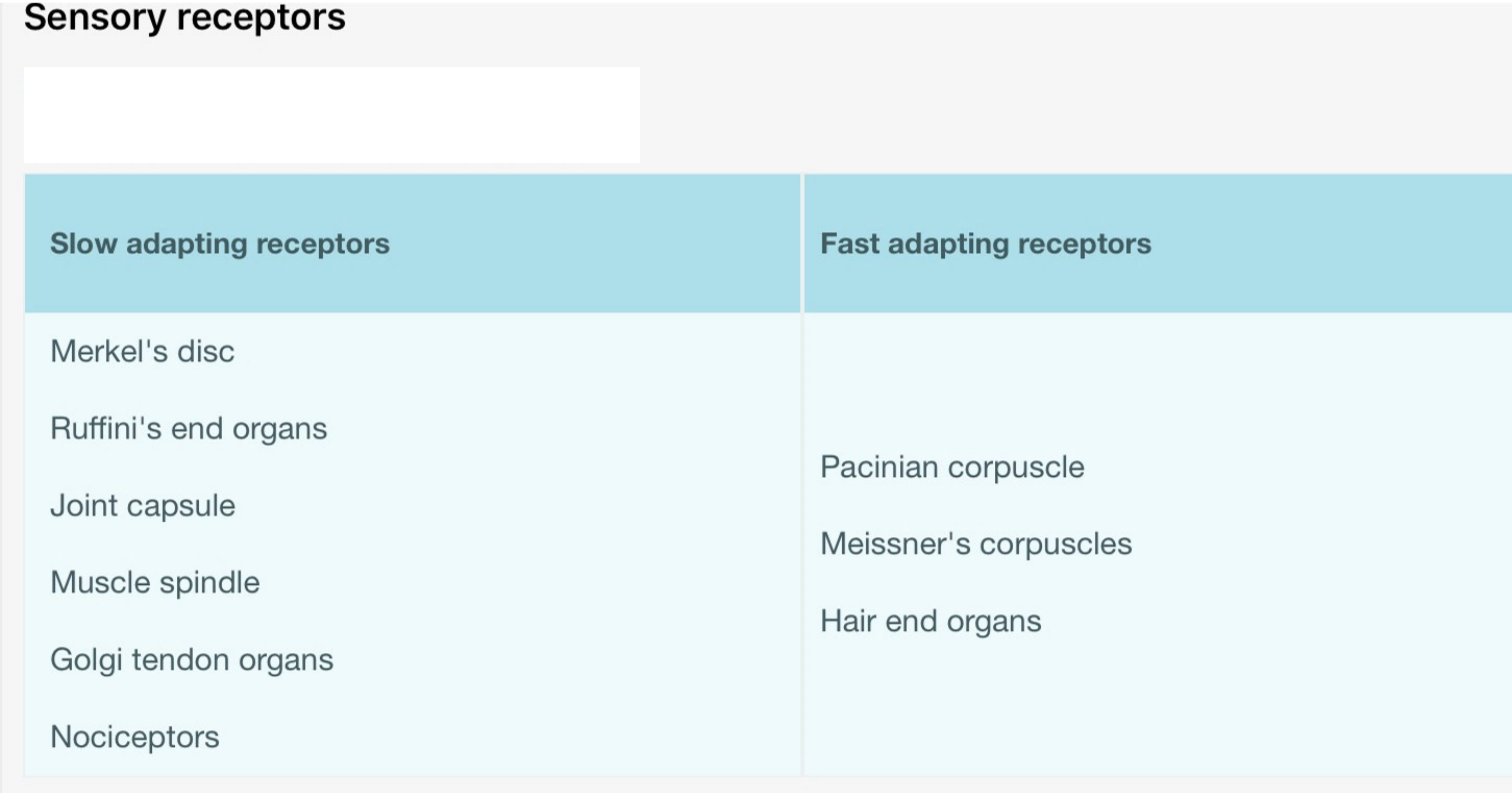
Pearl #2333 • Physiology

Term	Defnition	Site of lesion
Agnosia	Inability to accurately perceive objects through normally functioning sensory mechanisms	Posterior parietal cortex
Dyslexia (word blindness)	Inability to interpret their meanings (the person may be able to see words and even know that they are words but not be able to interpret their meanings)	Angular gyrus
Aphasia	inability to produce and/or understand language	All components of the language network are interconnected with each other and with surrounding parts of the frontal, parietal, and temporal lobes. Damage to this network gives rise to language impairments resulting in aphasia.



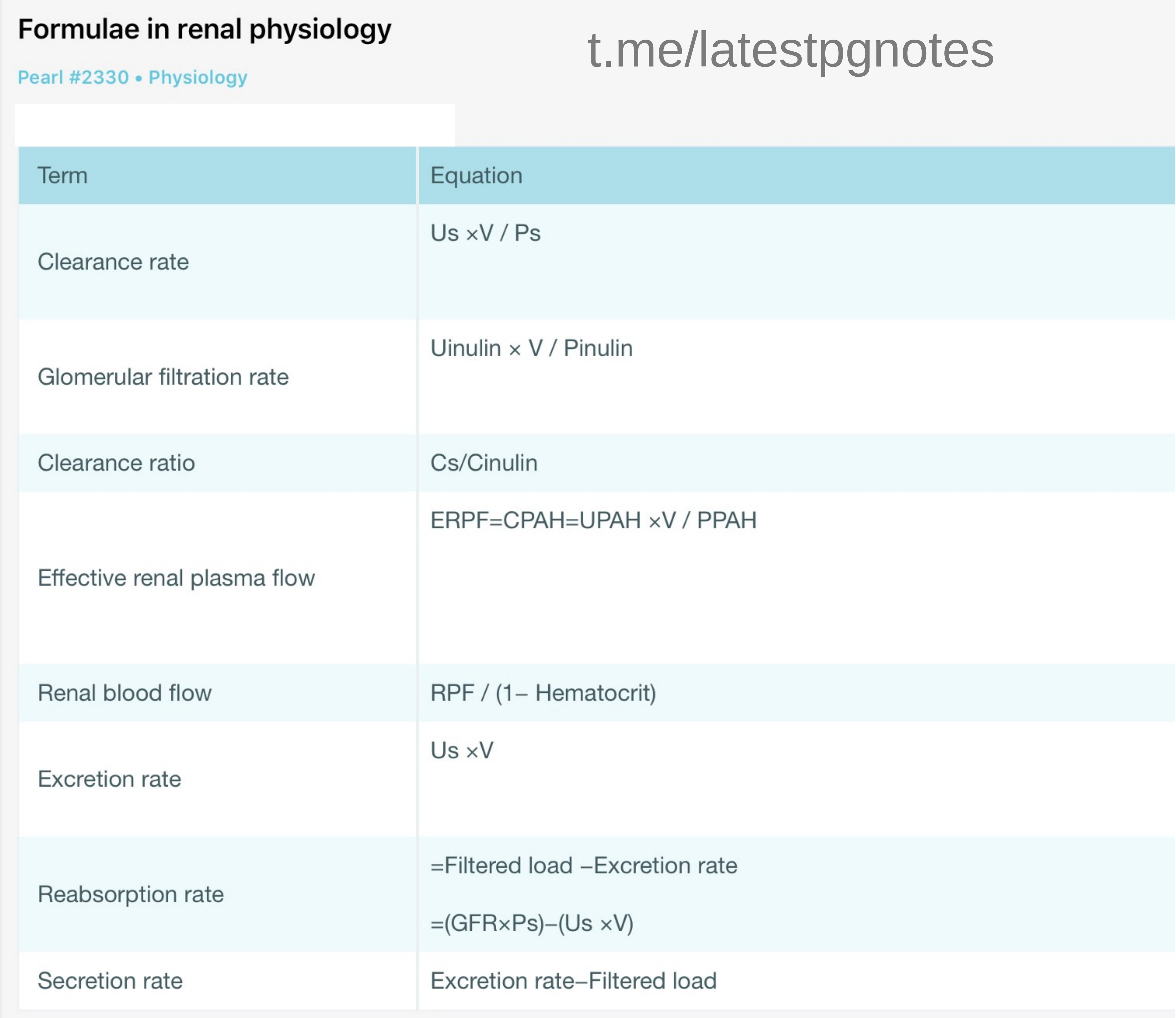
Sensory receptors

Slow adapting	Rapidly adapting receptors
Also called tonic receptors	Also called phasic receptors
They are expanded on free nerve endings.	They are encapsulated nerve endings.
Responds to steady stimulus	Respond to rate of change of stimulus
With steady stimulus, tonic receptors keep responding steadily.	With steady stimulus, receptor responds initially but stops or adapts rapidly.
Examples: Merkel's disc, Ruffini's end organs, Joint capsule, Muscle spindle, Golgi tendon organs	Examples: Pacinian corpuscle, Meissner's corpuscles, Hair end organs



Sensory receptors

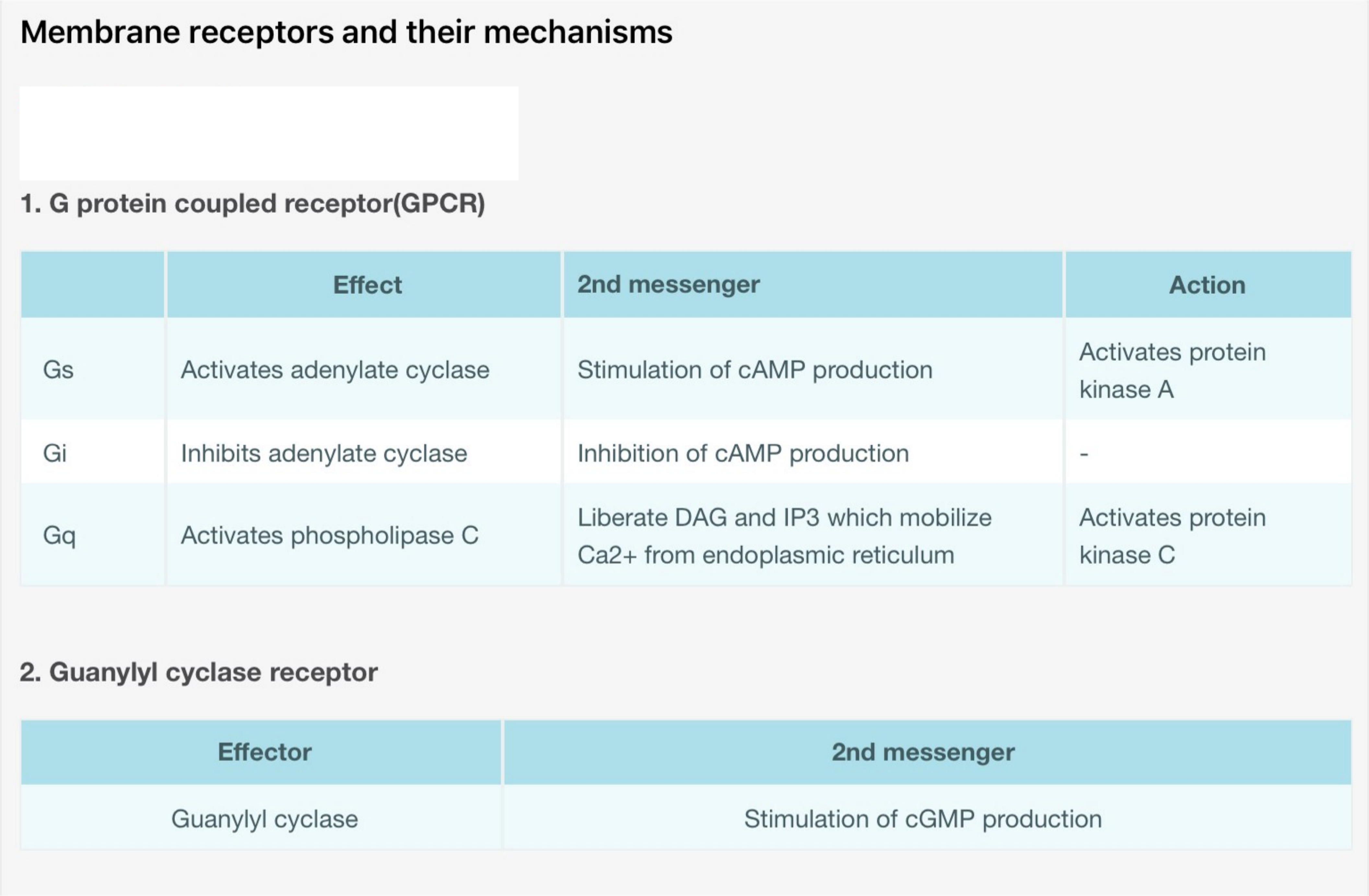
Slow adapting receptors	Fast adapting receptors
Merkel's disc Ruffini's end organs Joint capsule Muscle spindle Golgi tendon organs Nociceptors	Pacinian corpuscle Meissner's corpuscles Hair end organs



Formulae in renal physiology

Pearl #2330 • Physiology

Term	Equation
Clearance rate	Us ×V / Ps
Glomerular filtration rate	Uinulin × V / Pinulin
Clearance ratio	Cs/Cinulin
Effective renal plasma flow	ERPF=CPAH=UPAH ×V / PPAH
Renal blood flow	RPF / (1– Hematocrit)
Excretion rate	Us ×V
Reabsorption rate	=Filtered load –Excretion rate =(GFR×Ps)–(Us ×V)
Secretion rate	Excretion rate–Filtered load



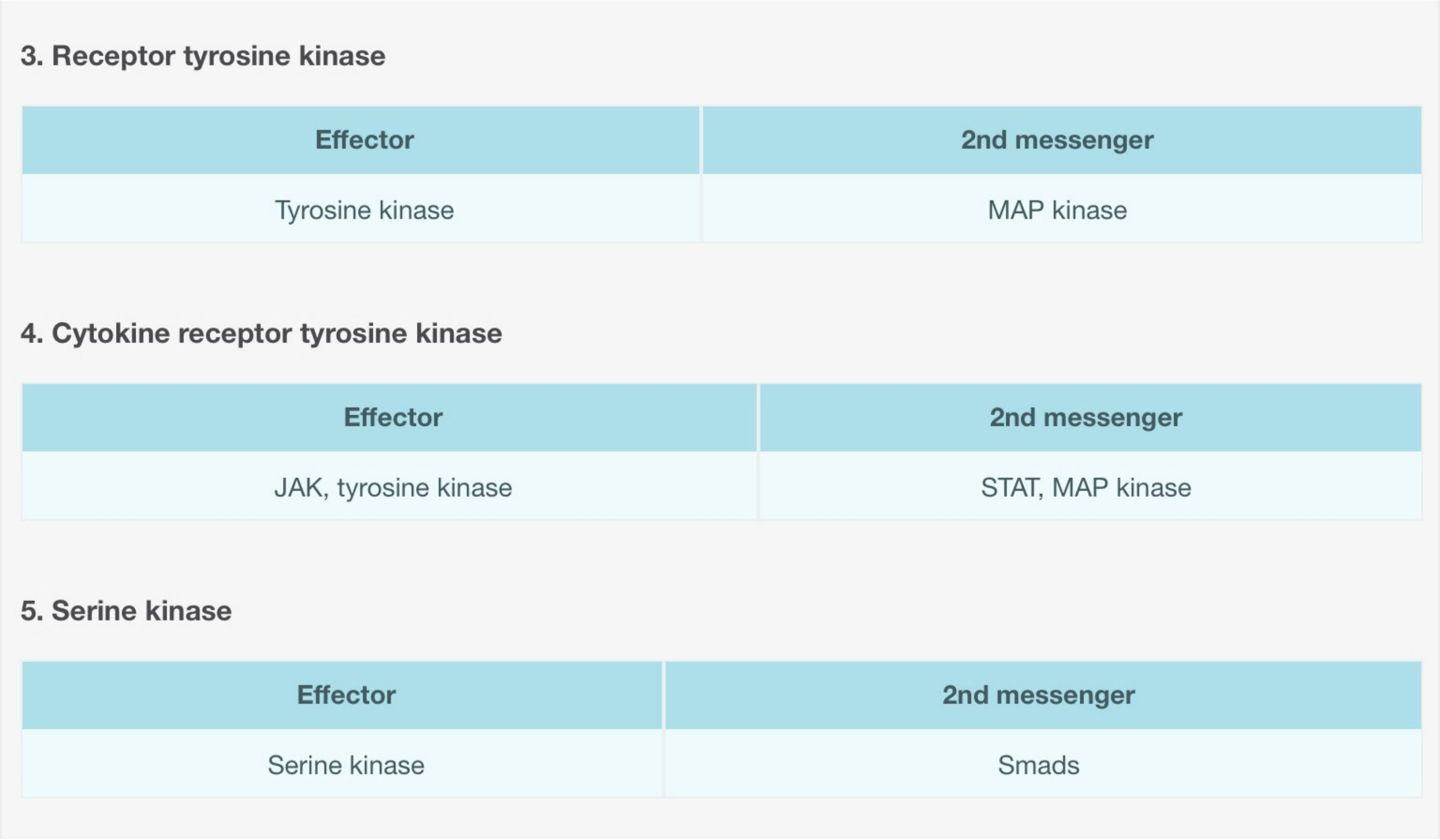
Membrane receptors and their mechanisms

1. G protein coupled receptor(GPCR)

	Effect	2nd messenger	Action
Gs	Activates adenylate cyclase	Stimulation of cAMP production	Activates protein kinase A
Gi	Inhibits adenylate cyclase	Inhibition of cAMP production	-
Gq	Activates phospholipase C	Liberate DAG and IP3 which mobilize Ca2+ from endoplasmic reticulum	Activates protein kinase C

2. Guanylyl cyclase receptor

Effector	2nd messenger
Guanylyl cyclase	Stimulation of cGMP production



3. Receptor tyrosine kinase

Effector	2nd messenger
Tyrosine kinase	MAP kinase

4. Cytokine receptor tyrosine kinase

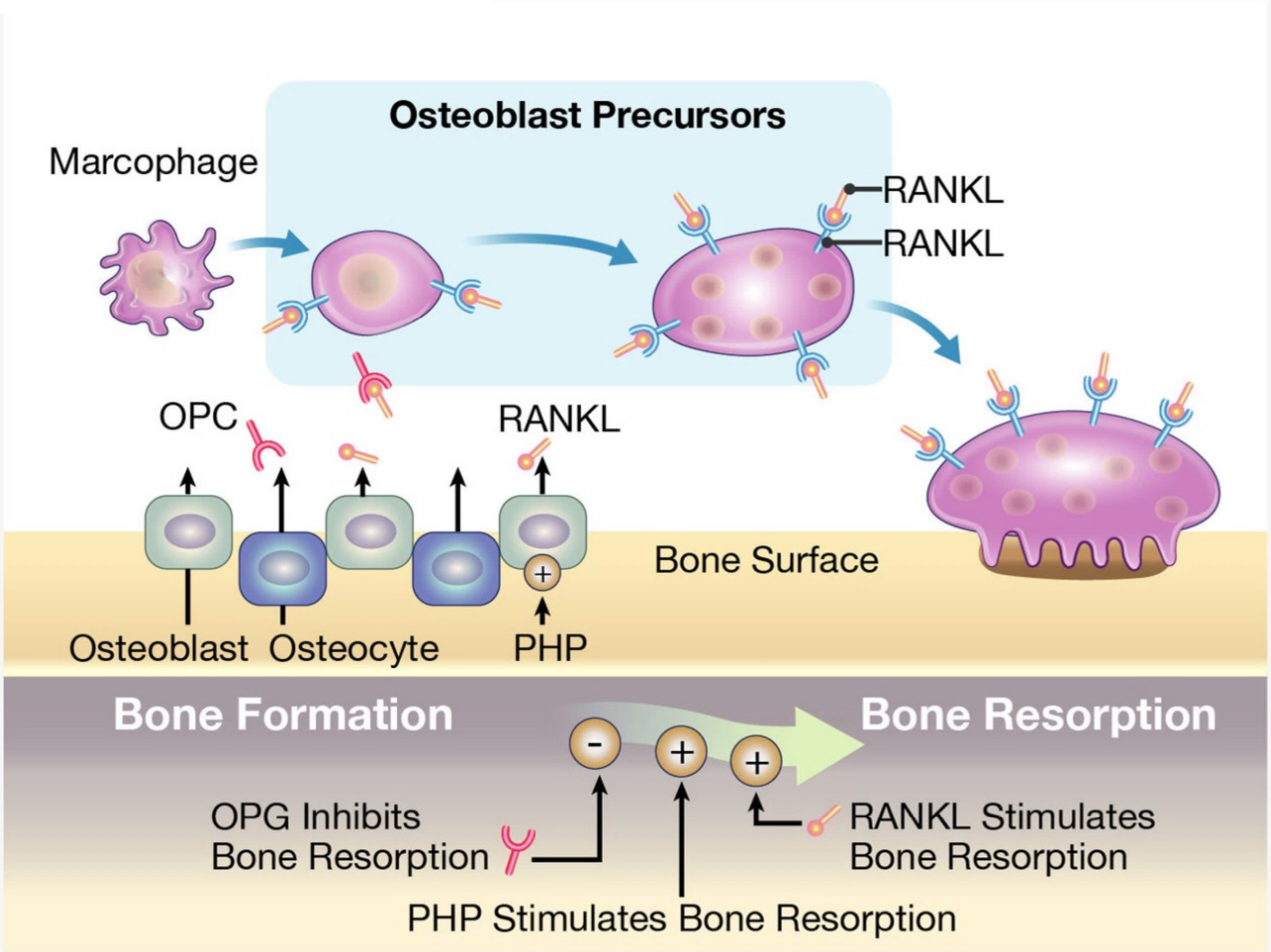
Effector	2nd messenger
JAK, tyrosine kinase	STAT, MAP kinase

5. Serine kinase

Effector	2nd messenger
Serine kinase	Smads

Bone formation and maturation

Pearl #2308 • Physiology



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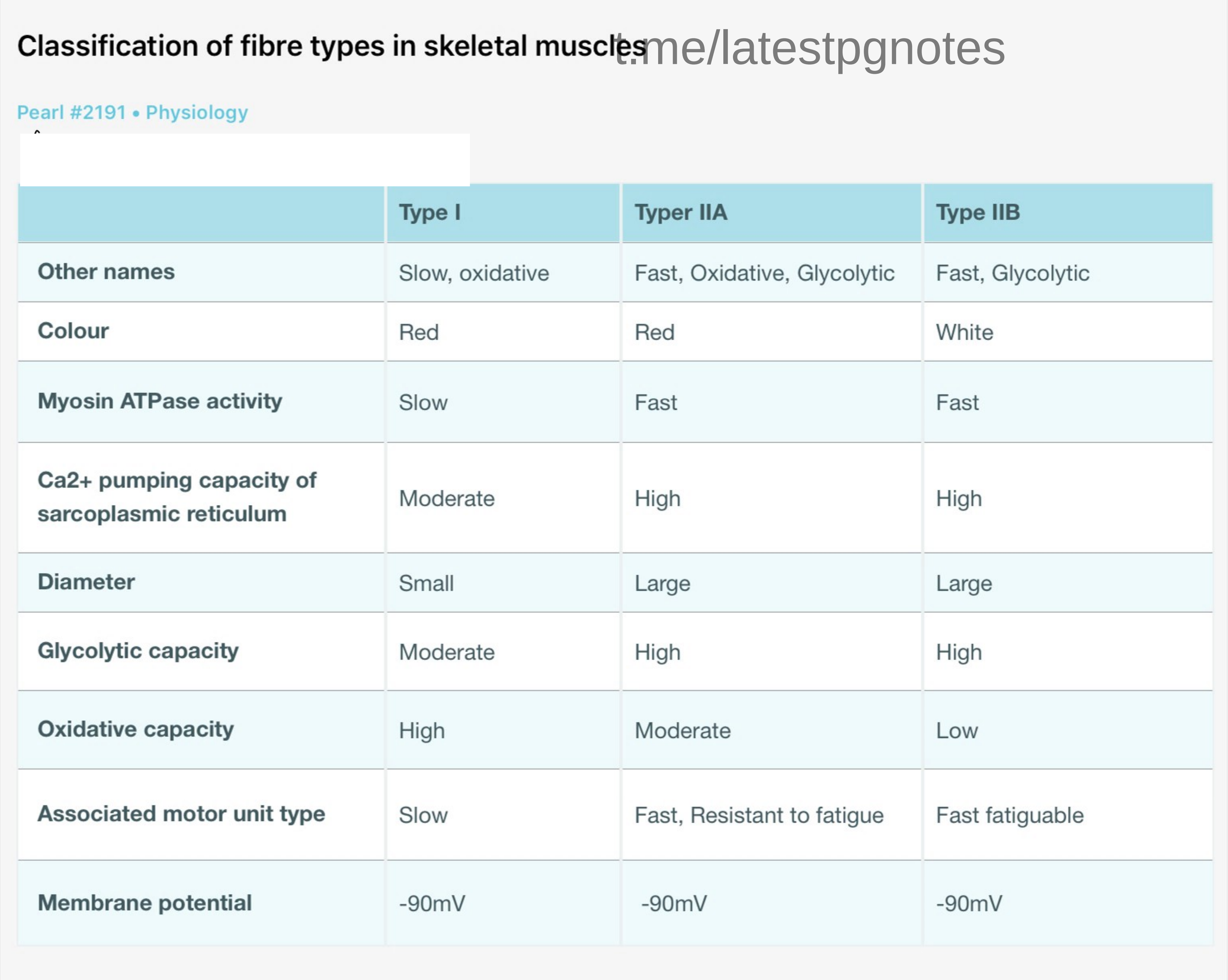
RANK Ligand (**RANK-L**) is produced by mature **osteoblasts and osteoblast progenitors.**

Osteoprotegerin also expressed by osteoblasts **binds to RANK-L** and reduces bone resorption.

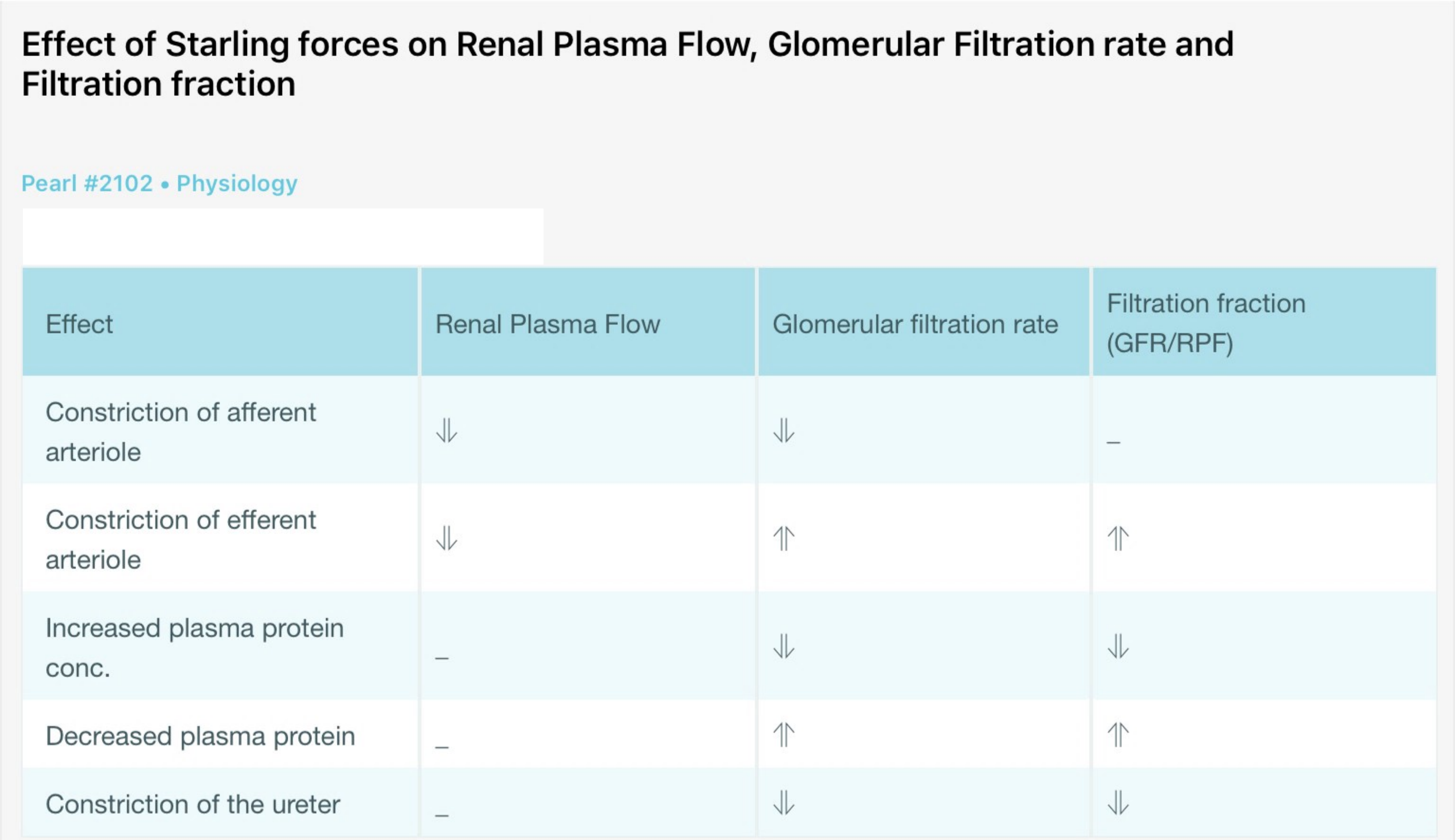
When RANK-L binds with RANK, it **stimulates osteoclastic proliferation** and differentiation leading to the formation of mature osteoclasts which results in bone resorption.



Classification of fibre types in skeletal muscles

Pearl #2191 • Physiology

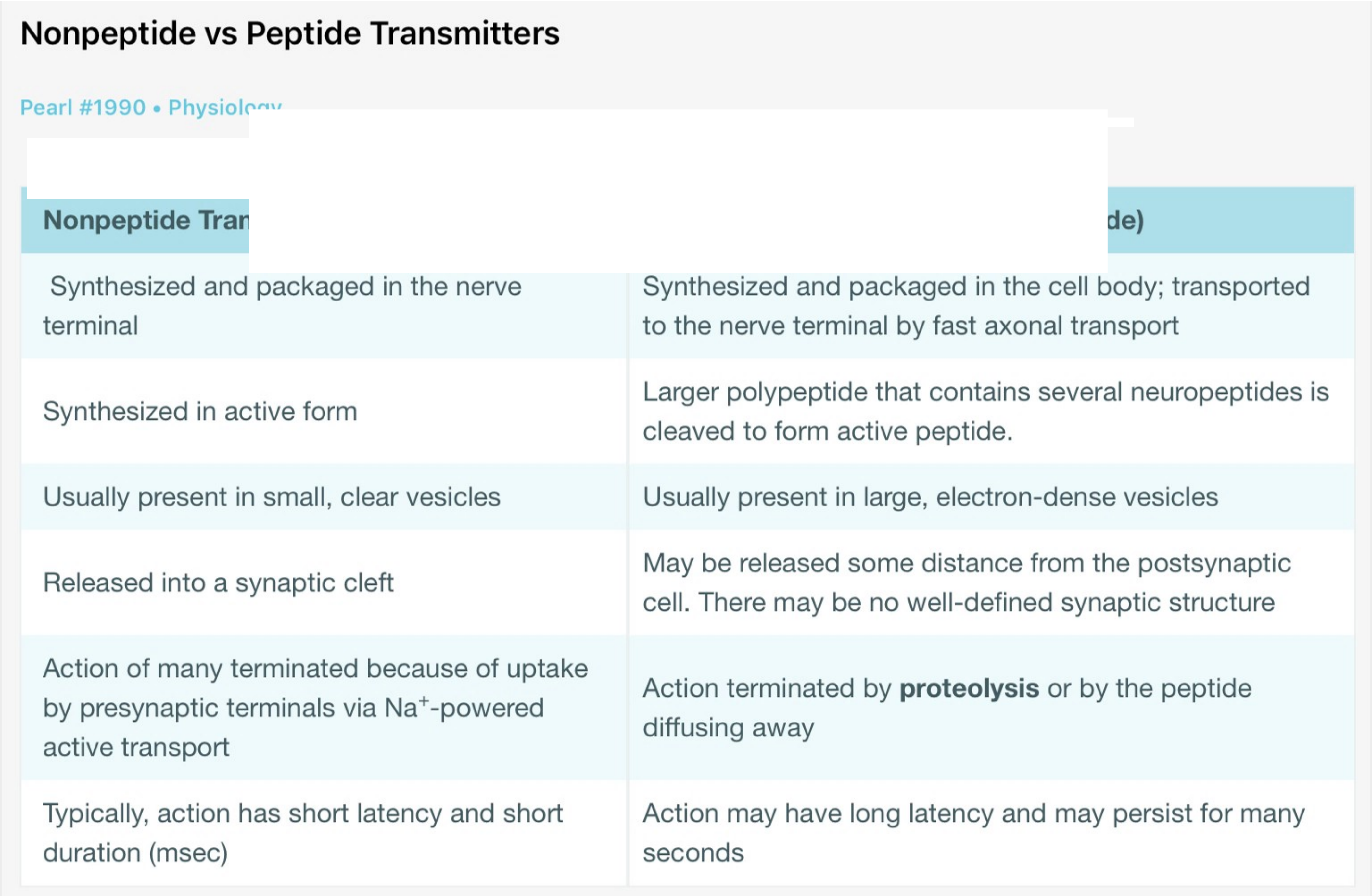
	Type I	Typer IIA	Type IIB
Other names	Slow, oxidative	Fast, Oxidative, Glycolytic	Fast, Glycolytic
Colour	Red	Red	White
Myosin ATPase activity	Slow	Fast	Fast
Ca2+ pumping capacity of sarcoplasmic reticulum	Moderate	High	High
Diameter	Small	Large	Large
Glycolytic capacity	Moderate	High	High
Oxidative capacity	High	Moderate	Low
Associated motor unit type	Slow	Fast, Resistant to fatigue	Fast fatiguable
Membrane potential	-90mV	-90mV	-90mV



Effect of Starling forces on Renal Plasma Flow, Glomerular Filtration rate and Filtration fraction

Pearl #2102 • Physiology

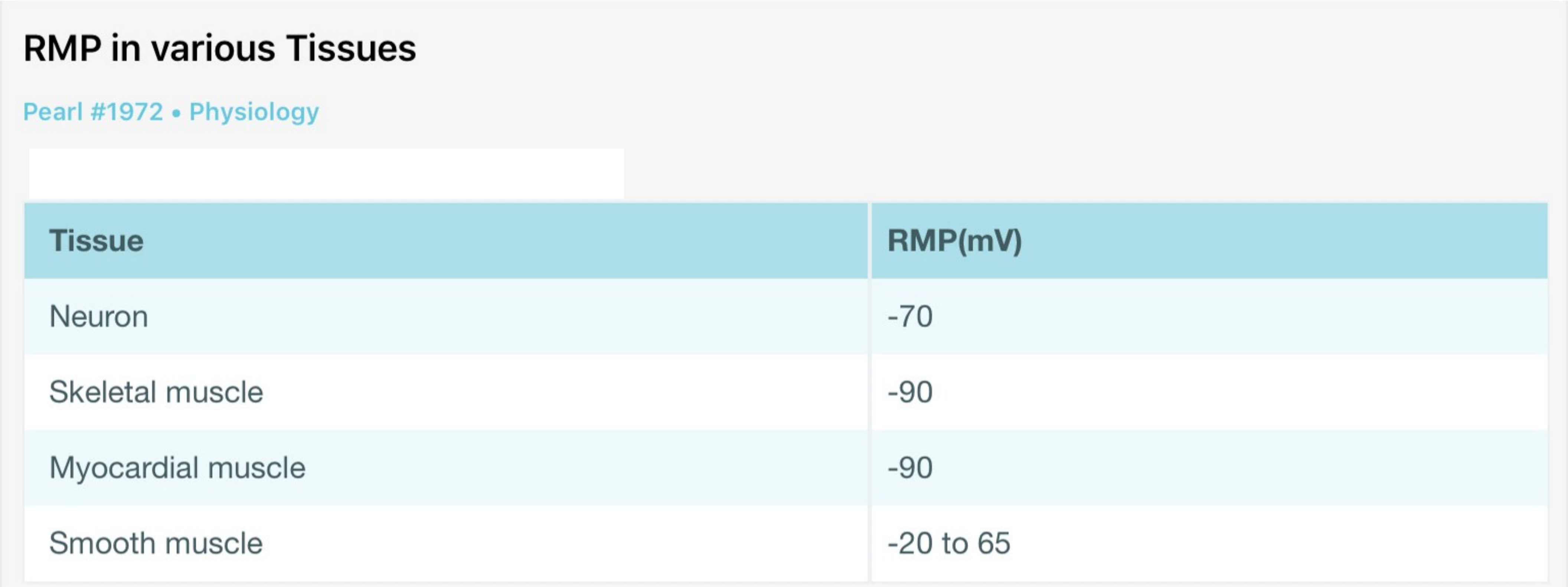
Effect	Renal Plasma Flow	Glomerular filtration rate	Filtration fraction (GFR/RPF)
Constriction of afferent arteriole	⇓	⇓	–
Constriction of efferent arteriole	⇓	⇑	⇑
Increased plasma protein conc.	–	⇓	⇓
Decreased plasma protein	–	⇑	⇑
Constriction of the ureter	–	⇓	⇓



Nonpeptide vs Peptide Transmitters

Pearl #1990 • Physiolo [redacted]

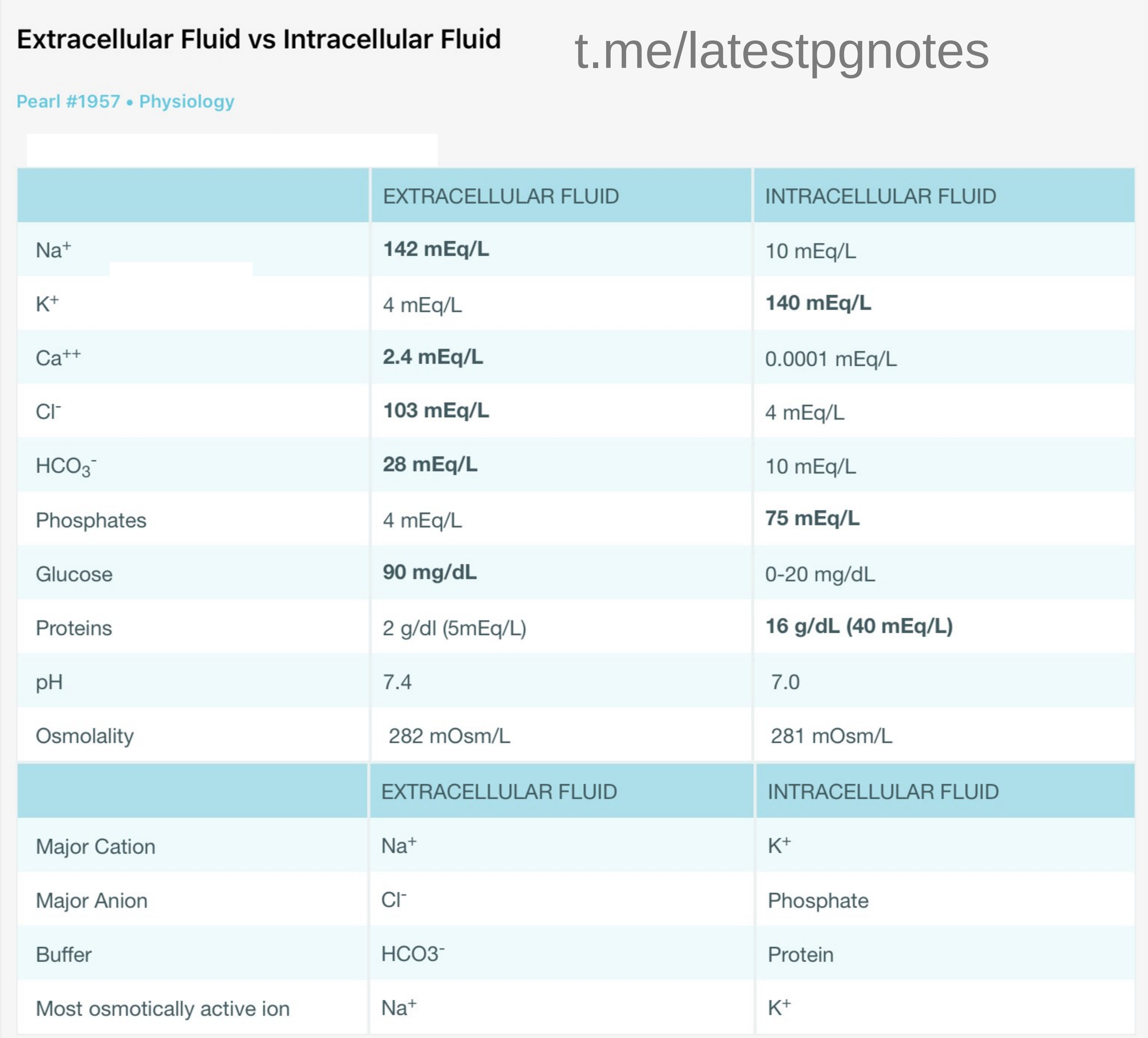
Nonpeptide Tran [redacted]	[redacted] de)
Synthesized and packaged in the nerve terminal	Synthesized and packaged in the cell body; transported to the nerve terminal by fast axonal transport
Synthesized in active form	Larger polypeptide that contains several neuropeptides is cleaved to form active peptide.
Usually present in small, clear vesicles	Usually present in large, electron-dense vesicles
Released into a synaptic cleft	May be released some distance from the postsynaptic cell. There may be no well-defined synaptic structure
Action of many terminated because of uptake by presynaptic terminals via Na^+-powered active transport	Action terminated by **proteolysis** or by the peptide diffusing away
Typically, action has short latency and short duration (msec)	Action may have long latency and may persist for many seconds



RMP in various Tissues

Pearl #1972 • Physiology

Tissue	RMP(mV)
Neuron	-70
Skeletal muscle	-90
Myocardial muscle	-90
Smooth muscle	-20 to 65

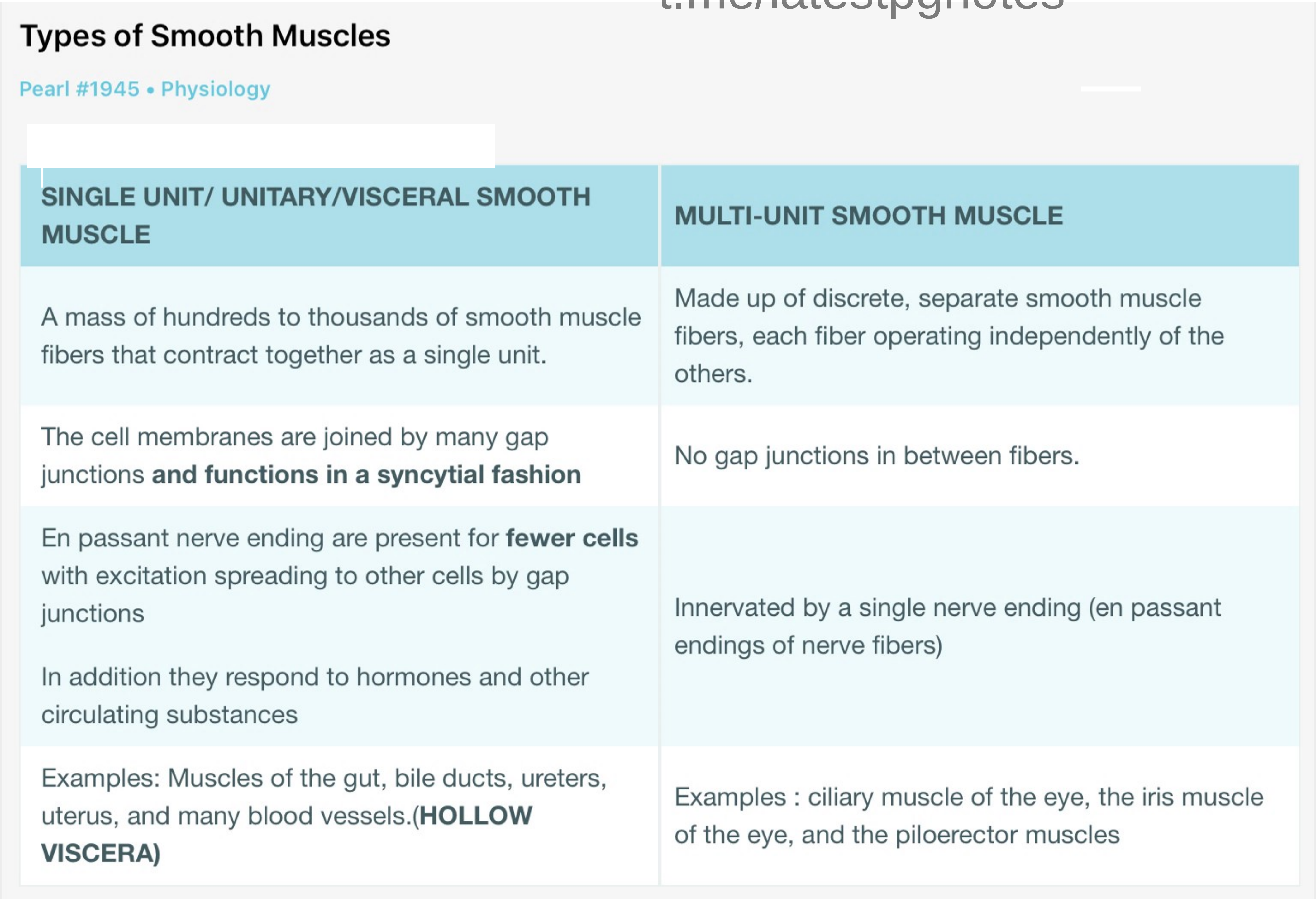


Extracellular Fluid vs Intracellular Fluid

Pearl #1957 • Physiology

	EXTRACELLULAR FLUID	INTRACELLULAR FLUID
Na^+	**142 mEq/L**	10 mEq/L
K^+	4 mEq/L	**140 mEq/L**
Ca^{++}	**2.4 mEq/L**	0.0001 mEq/L
Cl^-	**103 mEq/L**	4 mEq/L
HCO_3^-	**28 mEq/L**	10 mEq/L
Phosphates	4 mEq/L	**75 mEq/L**
Glucose	**90 mg/dL**	0-20 mg/dL
Proteins	2 g/dl (5mEq/L)	**16 g/dL (40 mEq/L)**
pH	7.4	7.0
Osmolality	282 mOsm/L	281 mOsm/L

	EXTRACELLULAR FLUID	INTRACELLULAR FLUID
Major Cation	Na^+	K^+
Major Anion	Cl^-	Phosphate
Buffer	$HCO3^-$	Protein
Most osmotically active ion	Na^+	K^+



Types of Smooth Muscles

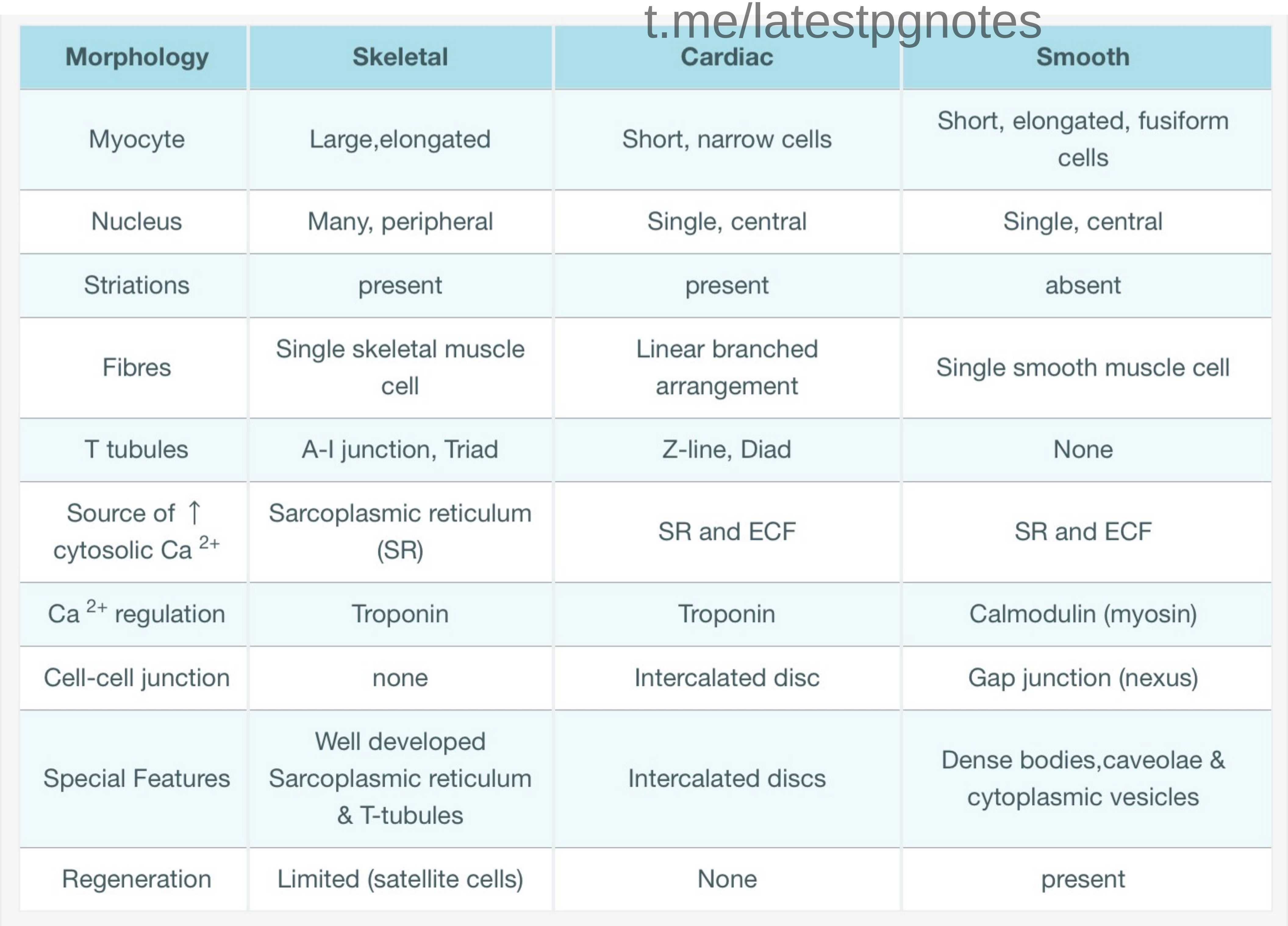
Pearl #1945 • Physiology

SINGLE UNIT/ UNITARY/VISCERAL SMOOTH MUSCLE	MULTI-UNIT SMOOTH MUSCLE
A mass of hundreds to thousands of smooth muscle fibers that contract together as a single unit.	Made up of discrete, separate smooth muscle fibers, each fiber operating independently of the others.
The cell membranes are joined by many gap junctions **and functions in a syncytial fashion**	No gap junctions in between fibers.
En passant nerve ending are present for **fewer cells** with excitation spreading to other cells by gap junctions In addition they respond to hormones and other circulating substances	Innervated by a single nerve ending (en passant endings of nerve fibers)
Examples: Muscles of the gut, bile ducts, ureters, uterus, and many blood vessels.(**HOLLOW VISCERA)**	Examples : ciliary muscle of the eye, the iris muscle of the eye, and the piloerector muscles

HEAT PRODUCTION IN MUSCLE

Pearl #1939 • Physiology

Heat Produced	Mechanism	Isotonic Contraction	Isometric Contraction
Resting heat	The heat given off at rest due to the basal metabolic processes.	+	+
Initial heat	The heat produced in excess of resting heat during contraction. • Activation heat: The heat that muscle produces whenever it is contracting • Shortening heat: Due to some change in the structure of the muscle during shortening.	+	+
Recovery Heat	This is the heat liberated by the metabolic processes that restore the muscle to its precontraction state. The recovery heat of muscle is approximately equal to the initial heat.	+	+
Relaxation Heat	Heat released in a muscle to restore it to its previous length. This extra heat is in addition to recovery heat.	+	-



Morphology	Skeletal	Cardiac	Smooth
Myocyte	Large,elongated	Short, narrow cells	Short, elongated, fusiform cells
Nucleus	Many, peripheral	Single, central	Single, central
Striations	present	present	absent
Fibres	Single skeletal muscle cell	Linear branched arrangement	Single smooth muscle cell
T tubules	A-I junction, Triad	Z-line, Diad	None
Source of ↑ cytosolic Ca^{2+}	Sarcoplasmic reticulum (SR)	SR and ECF	SR and ECF
Ca^{2+} regulation	Troponin	Troponin	Calmodulin (myosin)
Cell-cell junction	none	Intercalated disc	Gap junction (nexus)
Special Features	Well developed Sarcoplasmic reticulum & T-tubules	Intercalated discs	Dense bodies,caveolae & cytoplasmic vesicles
Regeneration	Limited (satellite cells)	None	present

Difference between Skeletal, Cardiac and Smooth Muscles.

Pearl #1938 • Physiology

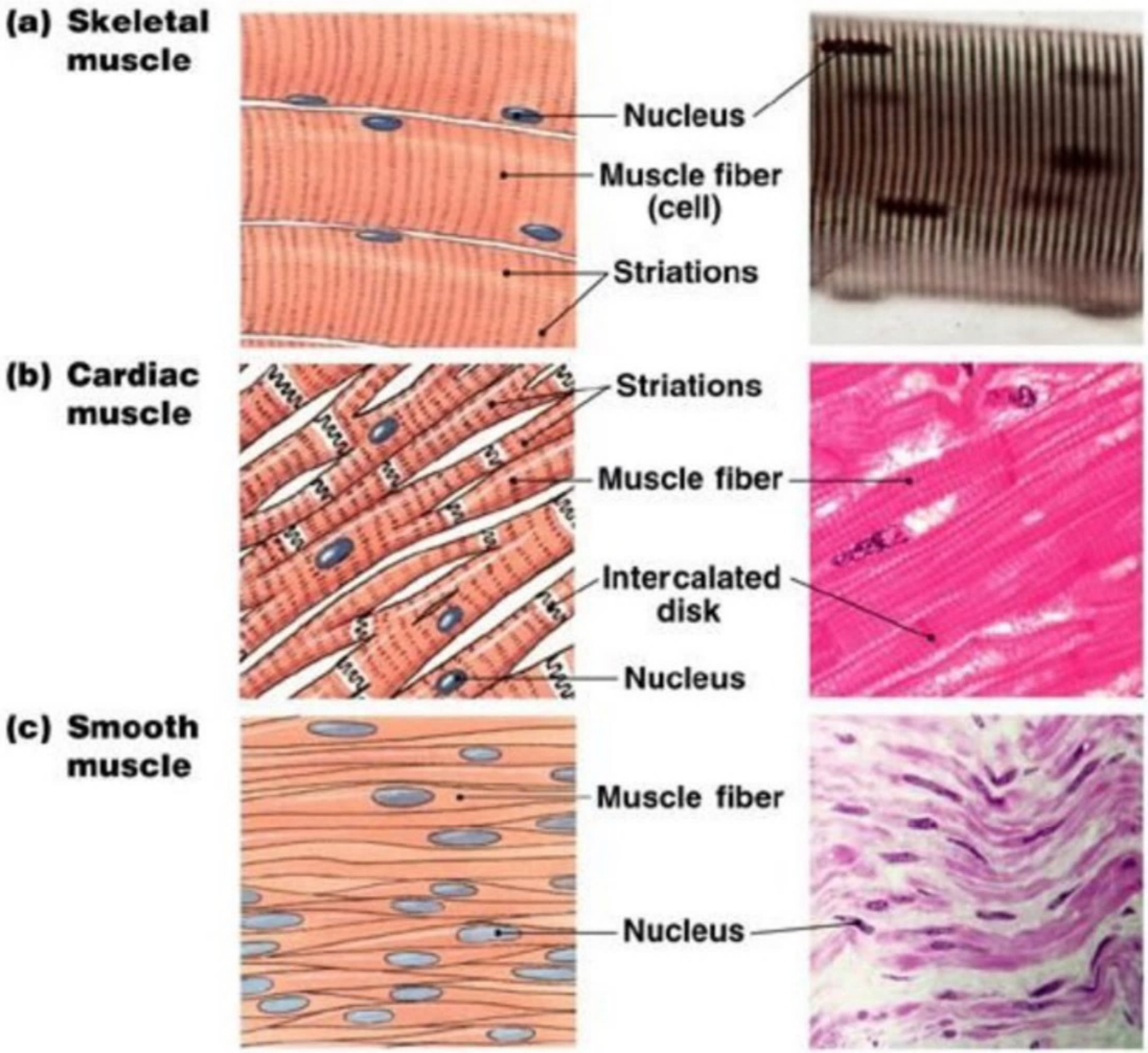


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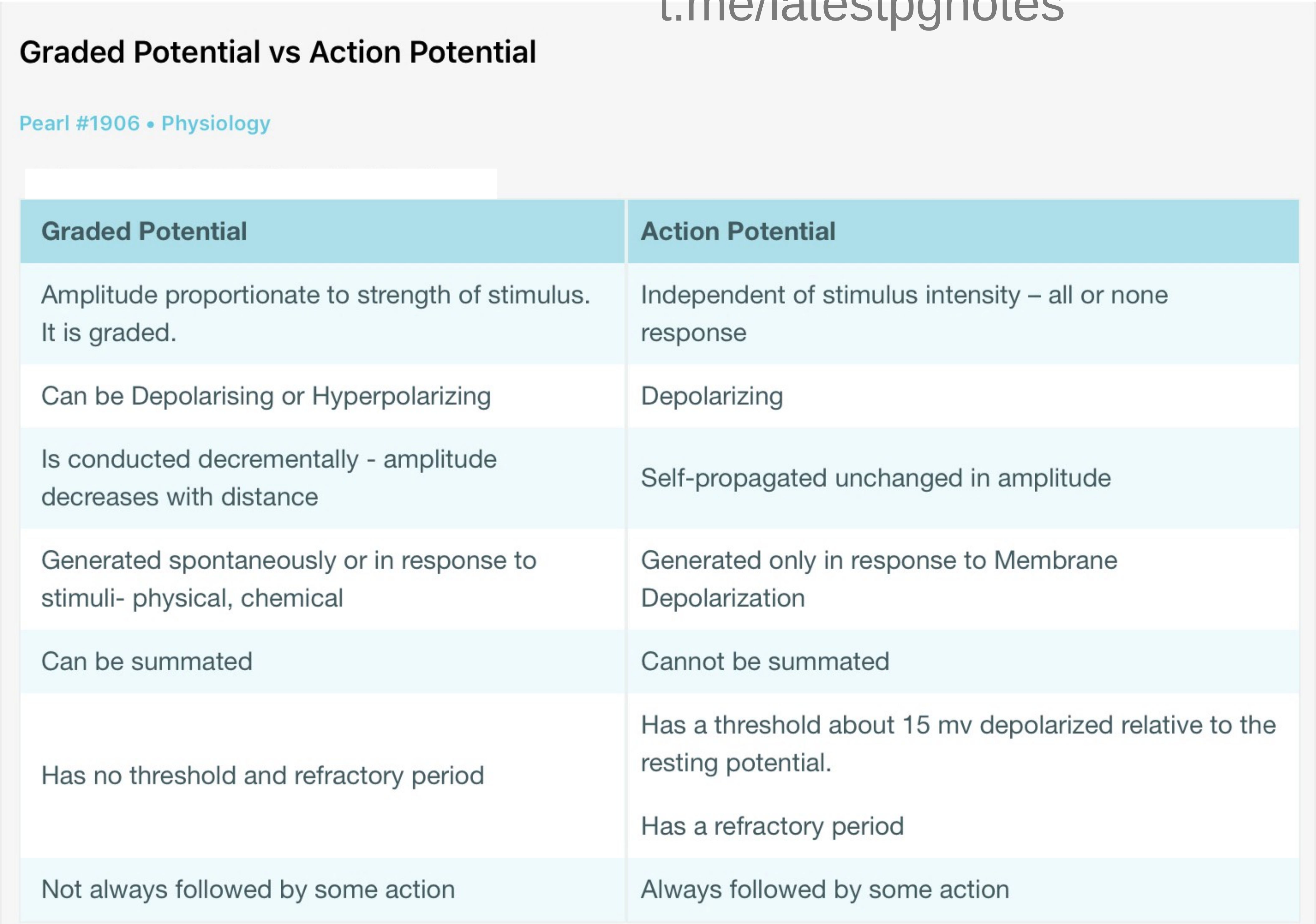
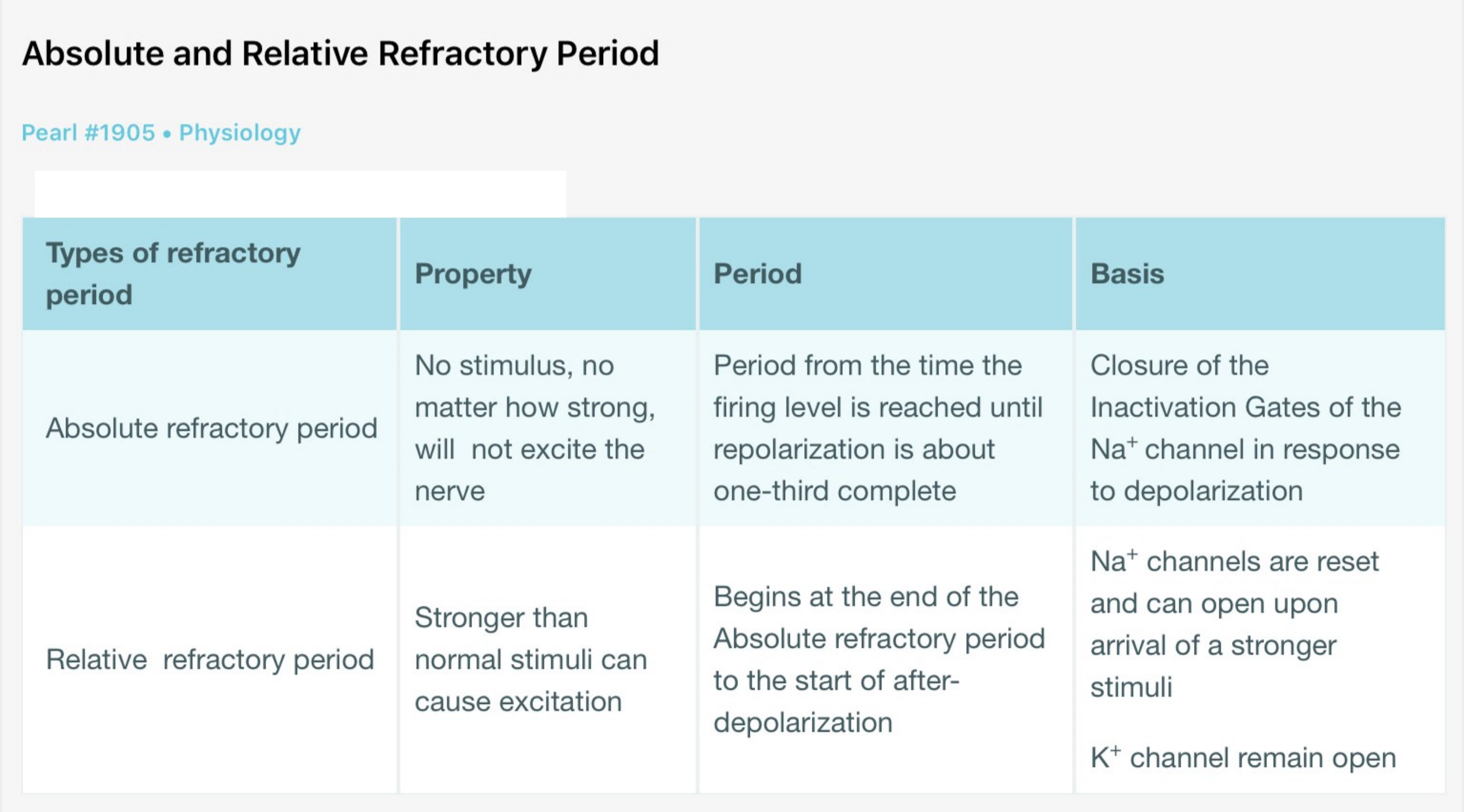
Fig. 12-1



Graded Potential vs Action Potential

Pearl #1906 • Physiology

Graded Potential	Action Potential
Amplitude proportionate to strength of stimulus. It is graded.	Independent of stimulus intensity – all or none response
Can be Depolarising or Hyperpolarizing	Depolarizing
Is conducted decrementally - amplitude decreases with distance	Self-propagated unchanged in amplitude
Generated spontaneously or in response to stimuli- physical, chemical	Generated only in response to Membrane Depolarization
Can be summated	Cannot be summated
Has no threshold and refractory period	Has a threshold about 15 mv depolarized relative to the resting potential. Has a refractory period
Not always followed by some action	Always followed by some action

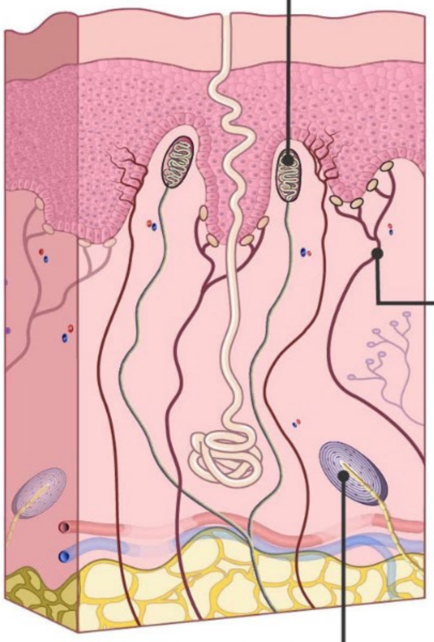


Absolute and Relative Refractory Period

Pearl #1905 • Physiology

Types of refractory period	Property	Period	Basis
Absolute refractory period	No stimulus, no matter how strong, will not excite the nerve	Period from the time the firing level is reached until repolarization is about one-third complete	Closure of the Inactivation Gates of the Na^+ channel in response to depolarization
Relative refractory period	Stronger than normal stimuli can cause excitation	Begins at the end of the Absolute refractory period to the start of after-depolarization	Na^+ channels are reset and can open upon arrival of a stronger stimuli K^+ channel remain open

Glabrous Skin



Meissner corpuscle - Encapsulated dendrites

- Rapidly adapting (Phasic receptors).
- Responds to changes in texture and slow vibrations.
- Used for two point discrimination.

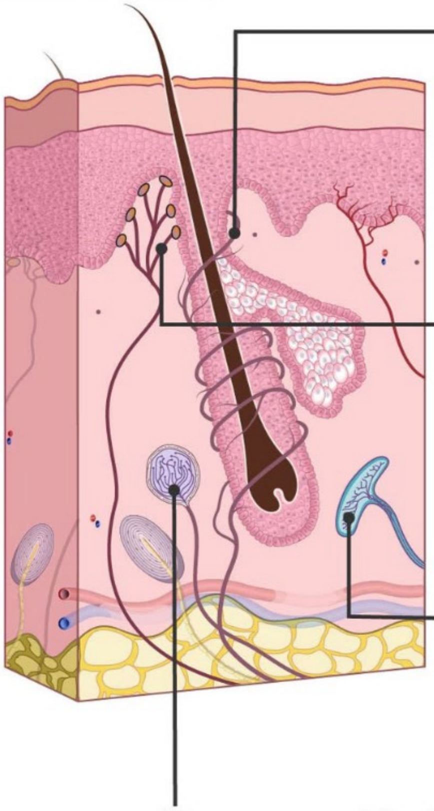
Merkel cells - Expanded dendritic endings

- Slowly adapting (Tonic receptors).
- Respond to sustained pressure and touch.

Pacinian corpuscle - Encapsulated dendrites

- Very rapidly adapting touch receptors.
- Responds specifically to fast vibration and deep pressure.

Hairy Skin



Hair end organs/hair follicle receptors - Rapidly adapting

- Detects velocity and direction of movement across the skin.

Tactile discs - Slowly adapting

- Similar to Merkel receptors in non hairy skin.
- Responds to sustained pressure.

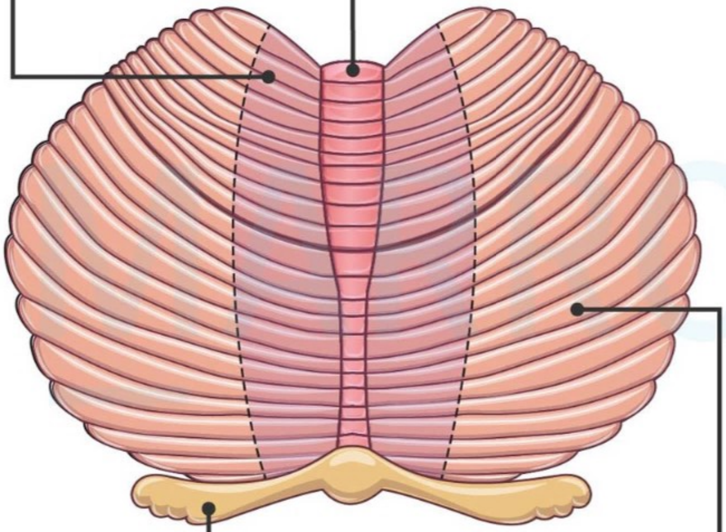
Ruffini corpuscle - Slowly adapting

- Respond to sustained pressure.

Krause end bulbs - Aids in thermal sensation.

Sensory Receptors

Ganong Review of Medical Physiology - 25th Edition, Pages 159-163



Medial part of cerebellar hemisphere
- Output via Interpositus nucleus which is composed of the Globose and Emboliform nuclei

Vermis
- Output via Fastigial nucleus

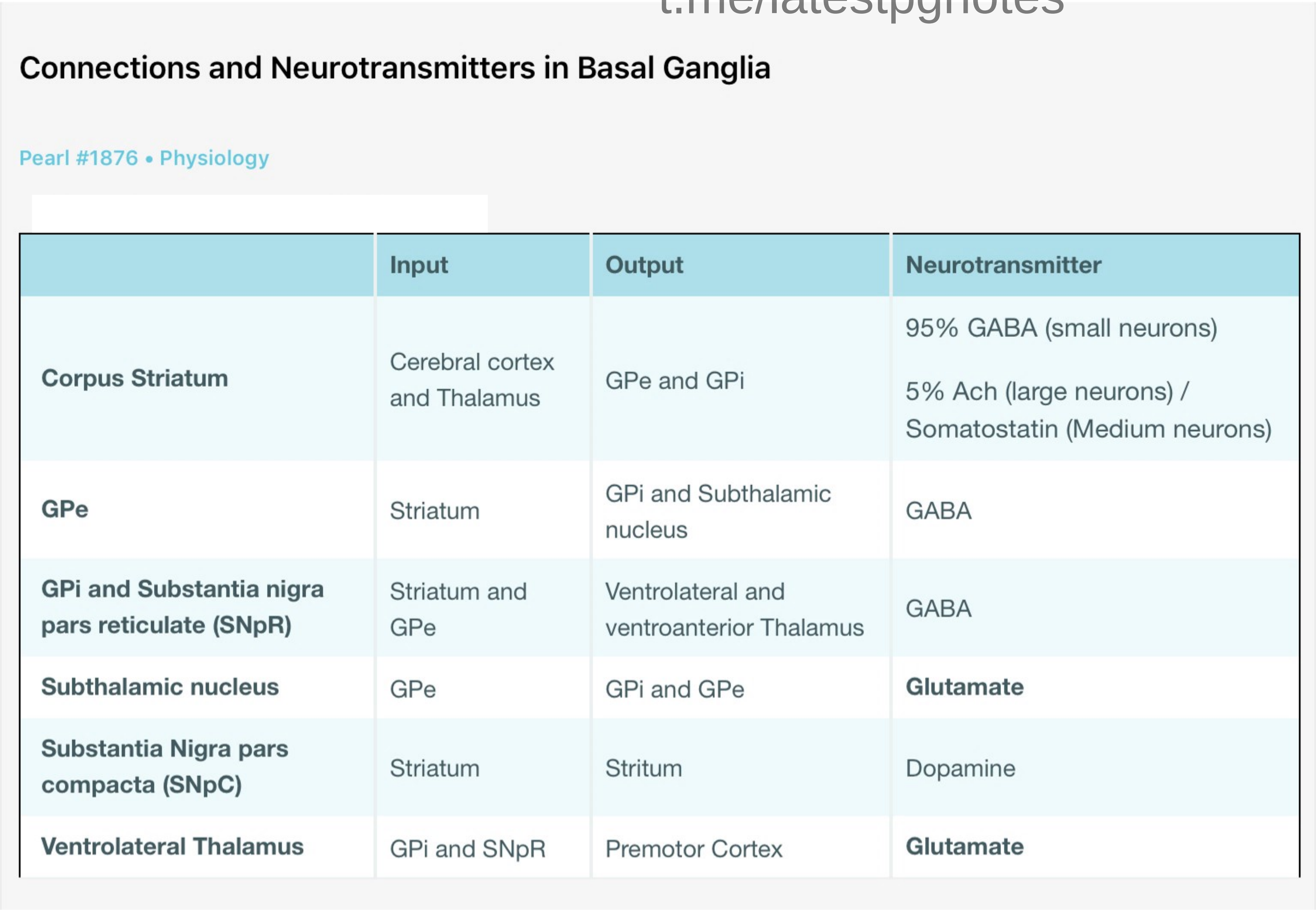
Spinocerebellum
- Also known as Paleocerebellum
- Function - Motor execution

Cerebrocerebellum
- Also called Neocerebellum
- Constituent - Lateral part of cerebellar hemisphere
- Output via Dentate nucleus to motor and premotor cortices
- Function - Motor planning

Vestibulocerebellum
- Also called Archicerebellum
- Constituent - Flocculonodular lobe
- Output to vestibular nuclei
- Function - Balance and eye movements

Functional Divisions of Cerebellum

Guyton and Hall Textbook of Medical Physiology,
13th Edition - Pages 721 - 726



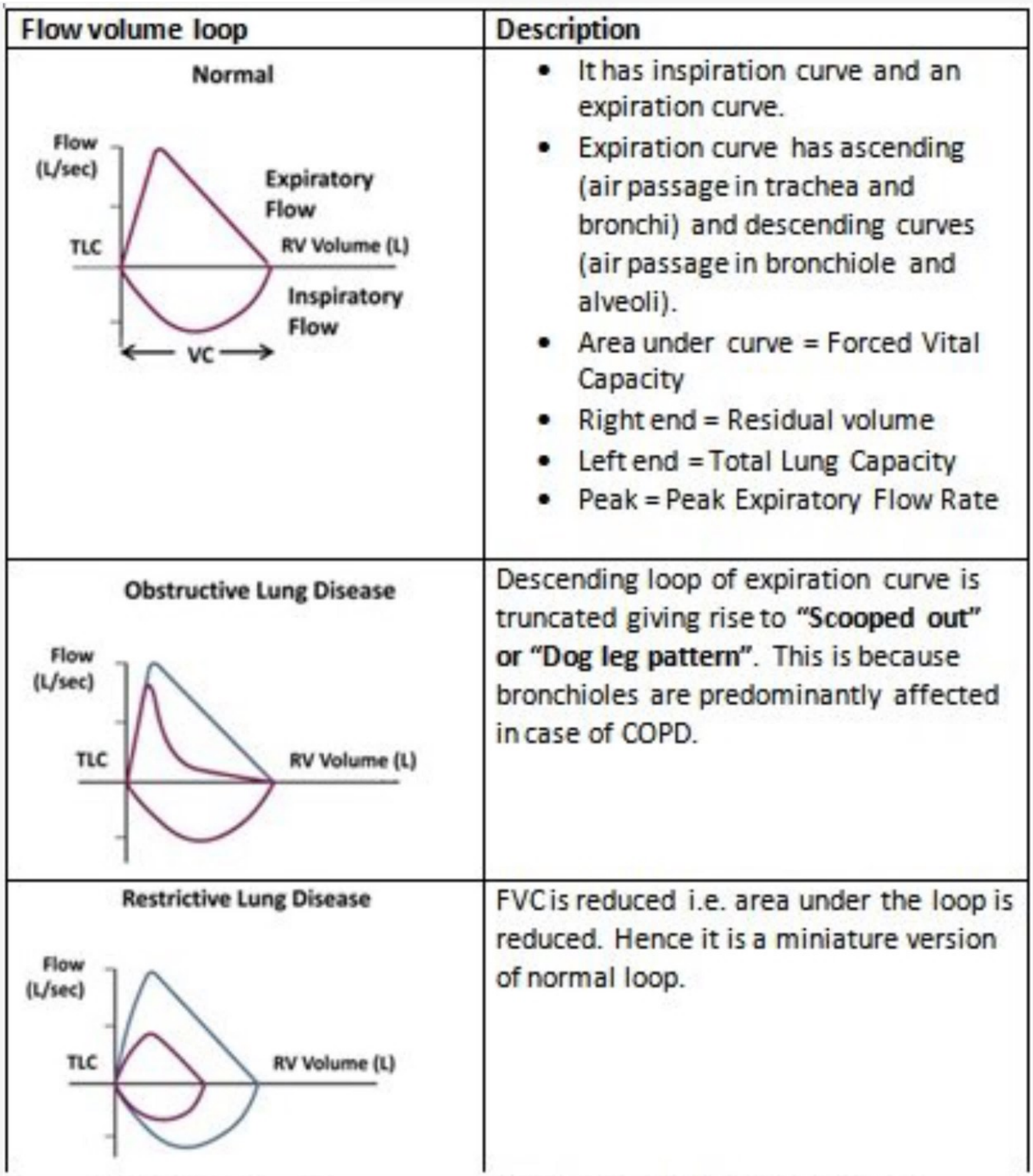
Connections and Neurotransmitters in Basal Ganglia

Pearl #1876 • Physiology

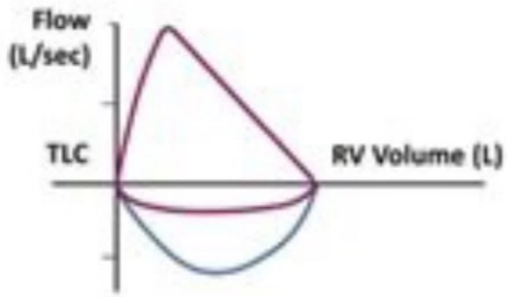
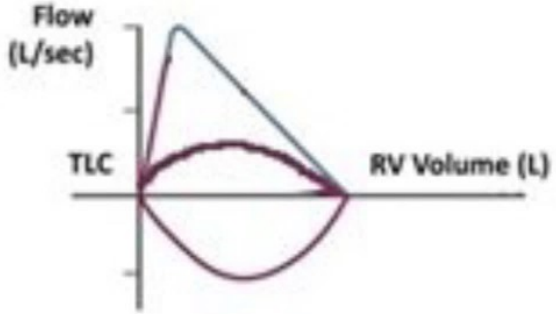
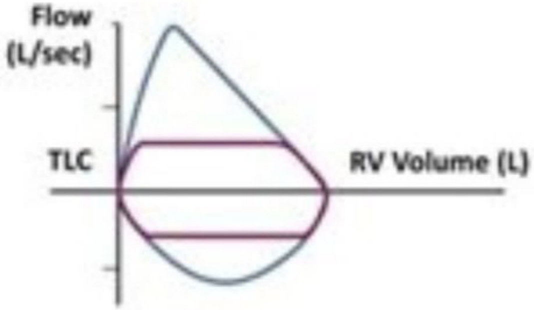
	Input	Output	Neurotransmitter
Corpus Striatum	Cerebral cortex and Thalamus	GPe and GPi	95% GABA (small neurons) 5% Ach (large neurons) / Somatostatin (Medium neurons)
GPe	Striatum	GPi and Subthalamic nucleus	GABA
GPi and Substantia nigra pars reticulate (SNpR)	Striatum and GPe	Ventrolateral and ventroanterior Thalamus	GABA
Subthalamic nucleus	GPe	GPi and GPe	**Glutamate**
Substantia Nigra pars compacta (SNpC)	Striatum	Stritum	Dopamine
Ventrolateral Thalamus	GPi and SNpR	Premotor Cortex	**Glutamate**

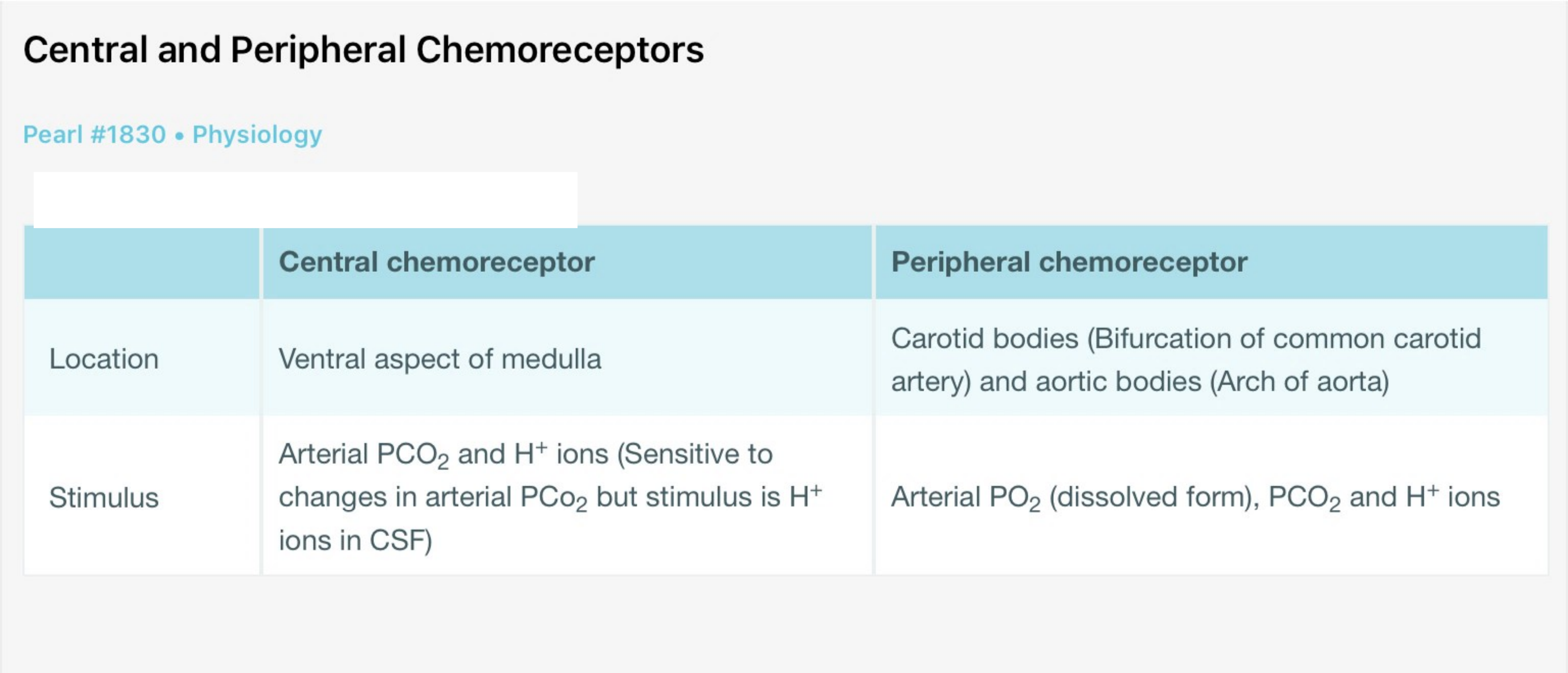
Flow-volume graph/Loop

Pearl #1835 • Physiology



Flow volume loop	Description
Normal	- It has inspiration curve and an expiration curve. - Expiration curve has ascending (air passage in trachea and bronchi) and descending curves (air passage in bronchiole and alveoli). - Area under curve = Forced Vital Capacity - Right end = Residual volume - Left end = Total Lung Capacity - Peak = Peak Expiratory Flow Rate
Obstructive Lung Disease	Descending loop of expiration curve is truncated giving rise to **"Scooped out" or "Dog leg pattern"**. This is because bronchioles are predominantly affected in case of COPD.
Restrictive Lung Disease	FVC is reduced i.e. area under the loop is reduced. Hence it is a miniature version of normal loop.

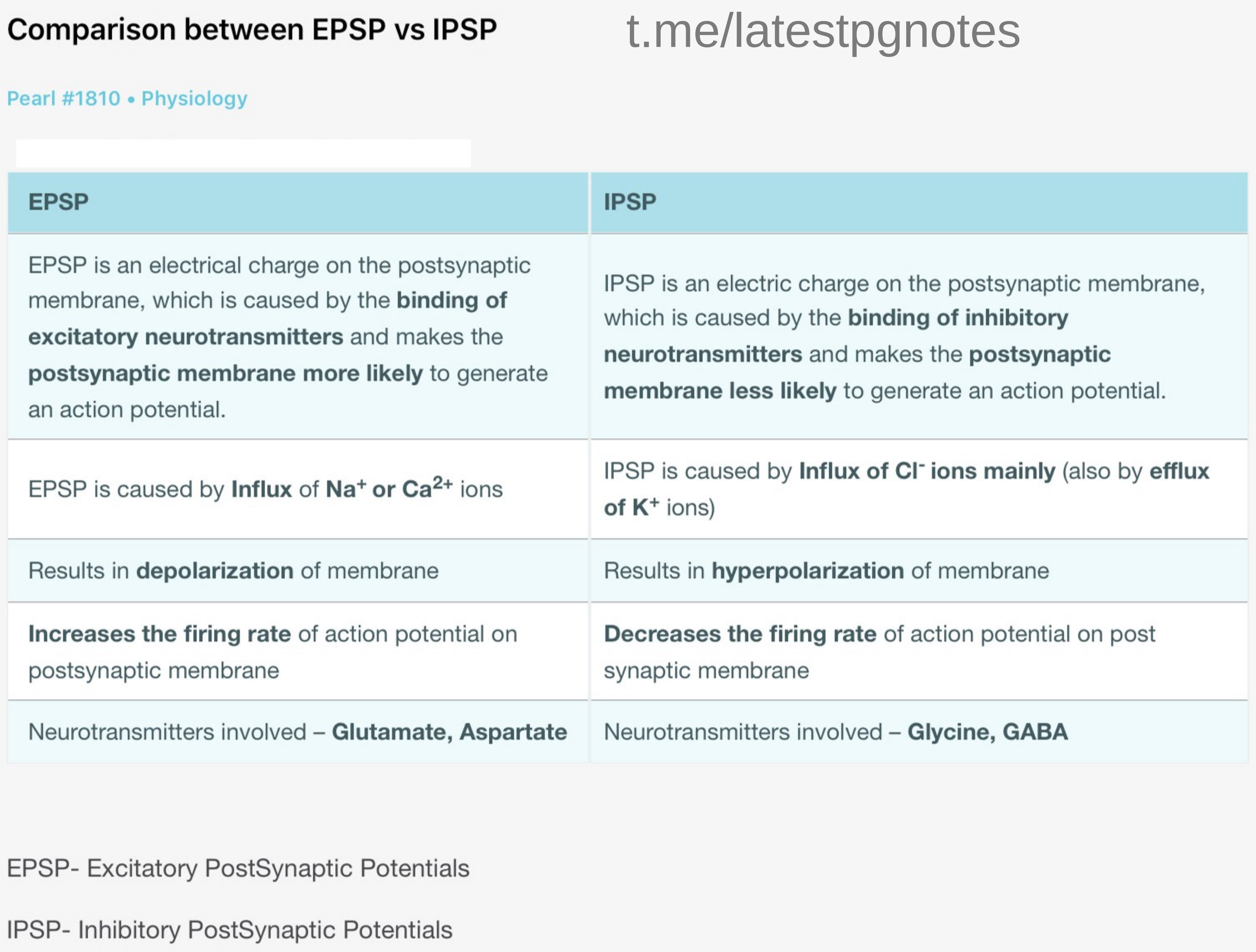
Variable Extrathoracic  	Expiratory part of the F/V-loop is normal. Obstruction is pushed outwards by the force of the expiration. During inspiration the obstruction is sucked into the trachea with partial obstruction and flattening of the inspiratory part of the flow-volume loop. This is seen in cases of obstructive sleep apnea, vocal cord paralysis, extrathoracic goiter and laryngeal tumors.
Variable intrathoracic obstruction  	This is opposite of Extrathoracic i.e. **expiratory curve is flattened.**
Fixed Upper Airway  	It can be both intrathoracic as extrathoracic. The flow-volume loop is **flattened during inspiration as well as expiration.** Examples are tracheal stenosis caused by intubation and a circular tracheal tumor.



Central and Peripheral Chemoreceptors

Pearl #1830 • Physiology

	Central chemoreceptor	**Peripheral chemoreceptor**
Location	Ventral aspect of medulla	Carotid bodies (Bifurcation of common carotid artery) and aortic bodies (Arch of aorta)
Stimulus	Arterial PCO_2 and H^+ ions (Sensitive to changes in arterial PCo_2 but stimulus is H^+ ions in CSF)	Arterial PO_2 (dissolved form), PCO_2 and H^+ ions



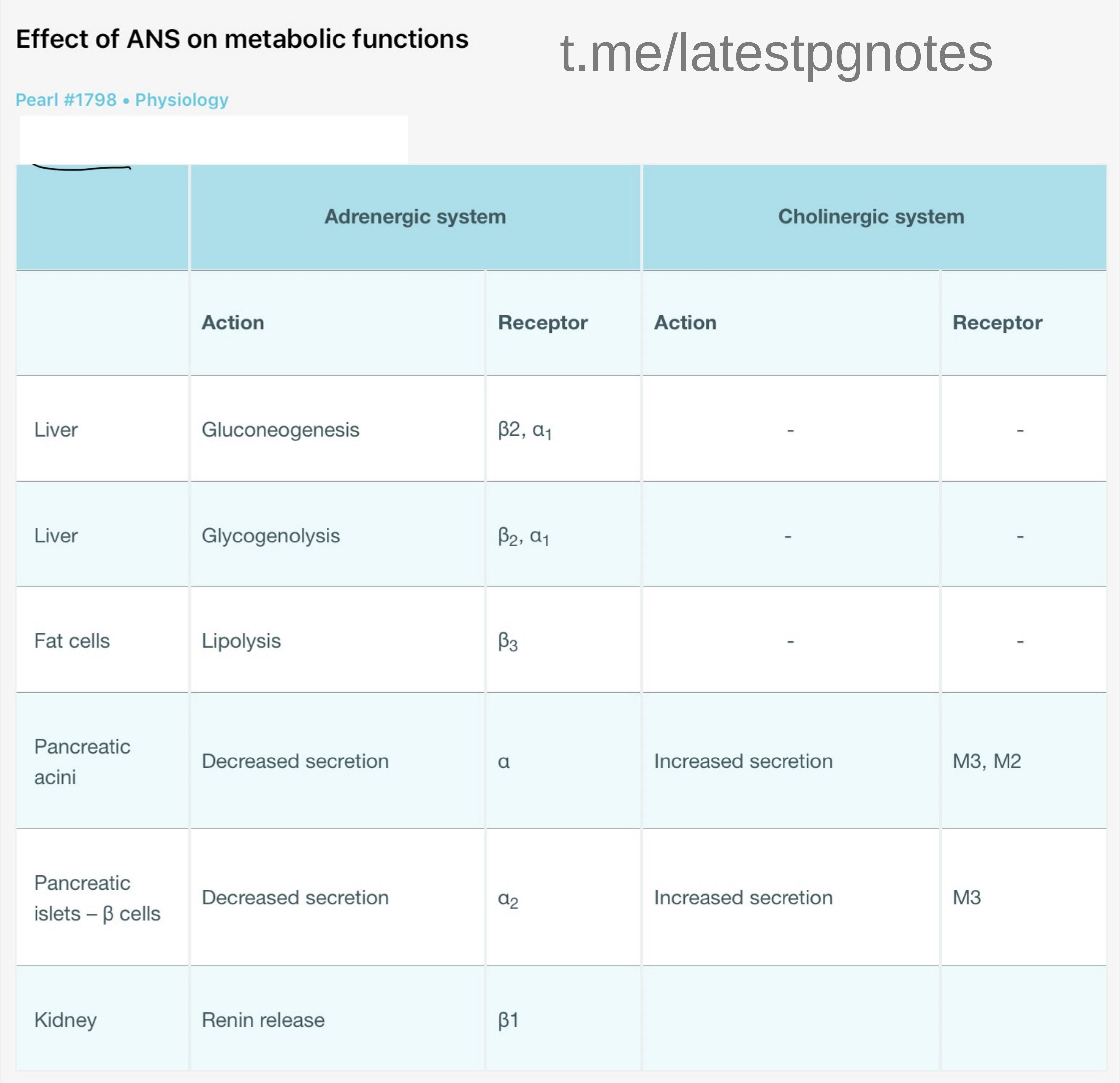
Comparison between EPSP vs IPSP

Pearl #1810 • Physiology

EPSP	IPSP
EPSP is an electrical charge on the postsynaptic membrane, which is caused by the **binding of excitatory neurotransmitters** and makes the **postsynaptic membrane more likely** to generate an action potential.	IPSP is an electric charge on the postsynaptic membrane, which is caused by the **binding of inhibitory neurotransmitters** and makes the **postsynaptic membrane less likely** to generate an action potential.
EPSP is caused by **Influx** of **Na^+ or Ca^{2+}** ions	IPSP is caused by **Influx of Cl^- ions mainly** (also by **efflux of K^+** ions)
Results in **depolarization** of membrane	Results in **hyperpolarization** of membrane
Increases the firing rate of action potential on postsynaptic membrane	**Decreases the firing rate** of action potential on post synaptic membrane
Neurotransmitters involved – **Glutamate, Aspartate**	Neurotransmitters involved – **Glycine, GABA**

EPSP- Excitatory PostSynaptic Potentials

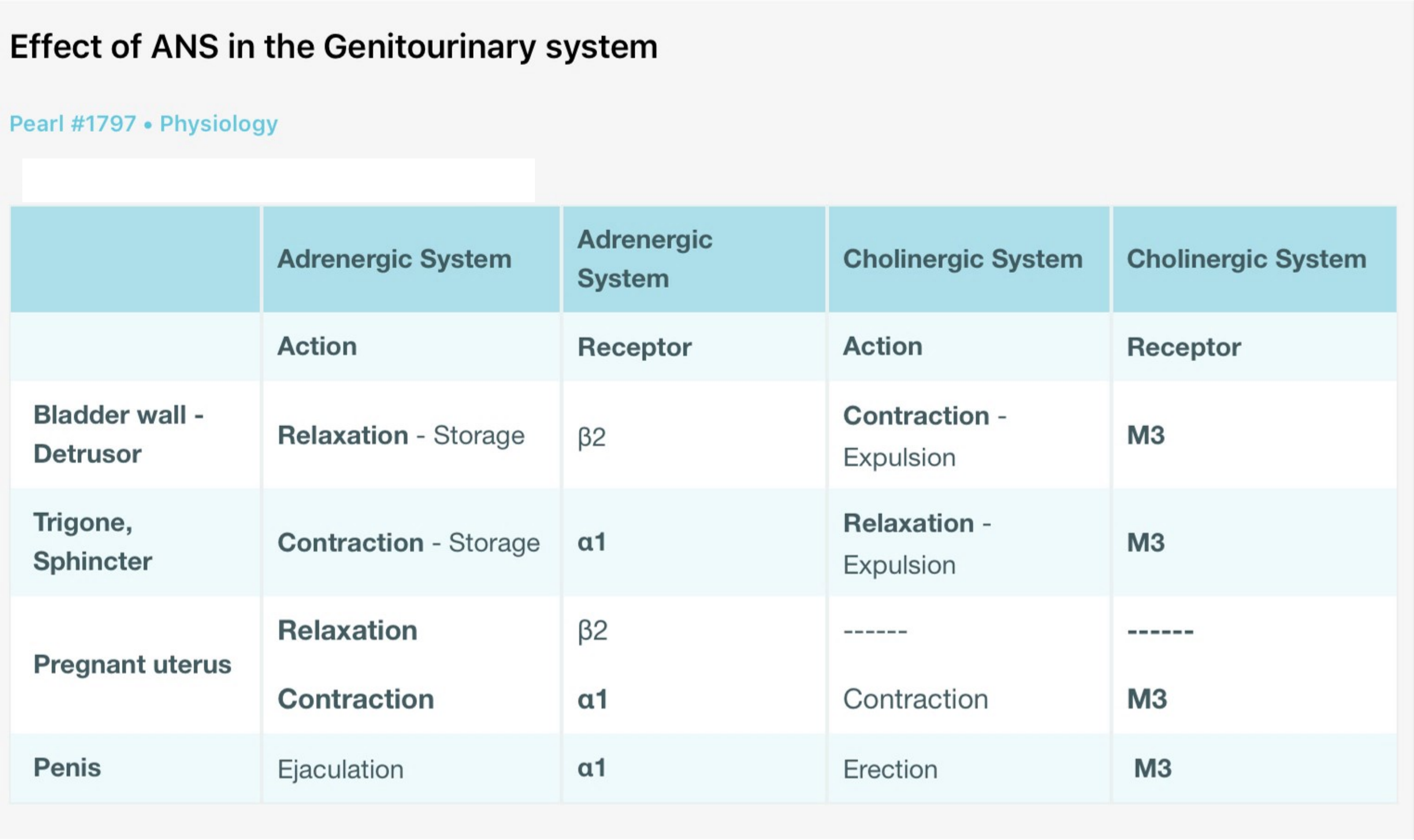
IPSP- Inhibitory PostSynaptic Potentials



Effect of ANS on metabolic functions

Pearl #1798 • Physiology

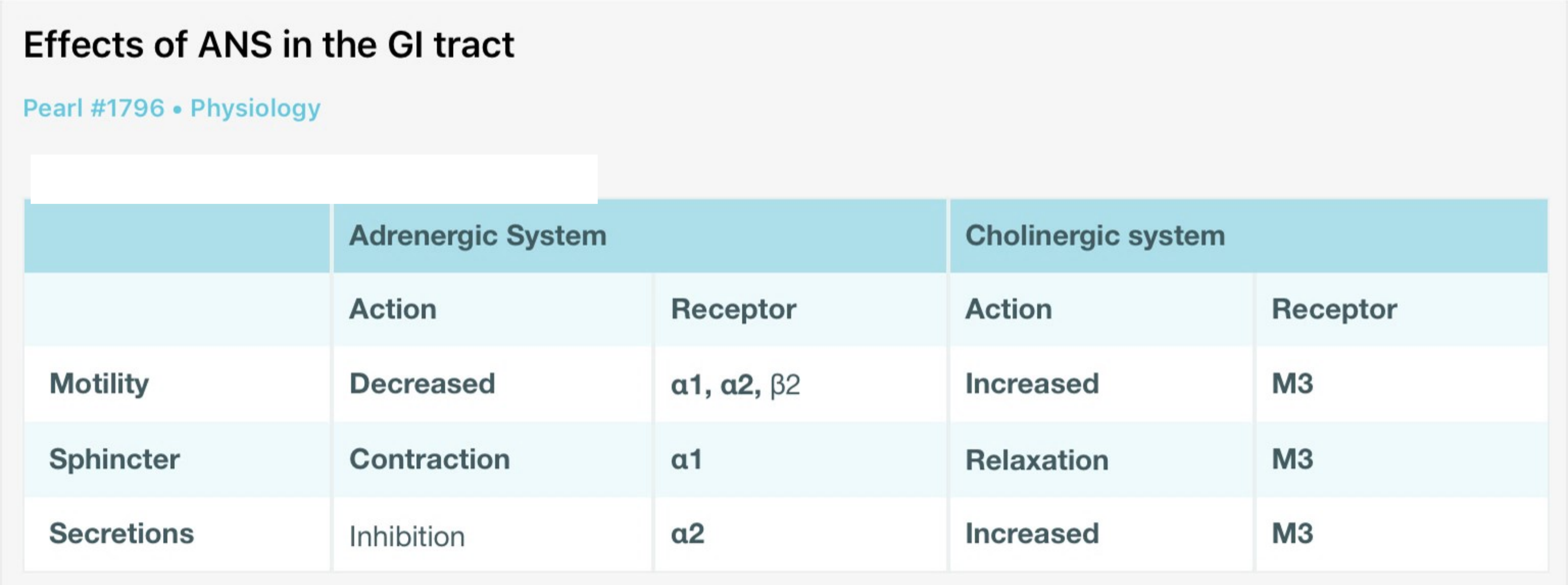
	Adrenergic system		Cholinergic system	
	Action	**Receptor**	**Action**	**Receptor**
Liver	Gluconeogenesis	β2, α_1	-	-
Liver	Glycogenolysis	β_2, α_1	-	-
Fat cells	Lipolysis	β_3	-	-
Pancreatic acini	Decreased secretion	α	Increased secretion	M3, M2
Pancreatic islets – β cells	Decreased secretion	α_2	Increased secretion	M3
Kidney	Renin release	β1		



Effect of ANS in the Genitourinary system

Pearl #1797 • Physiology

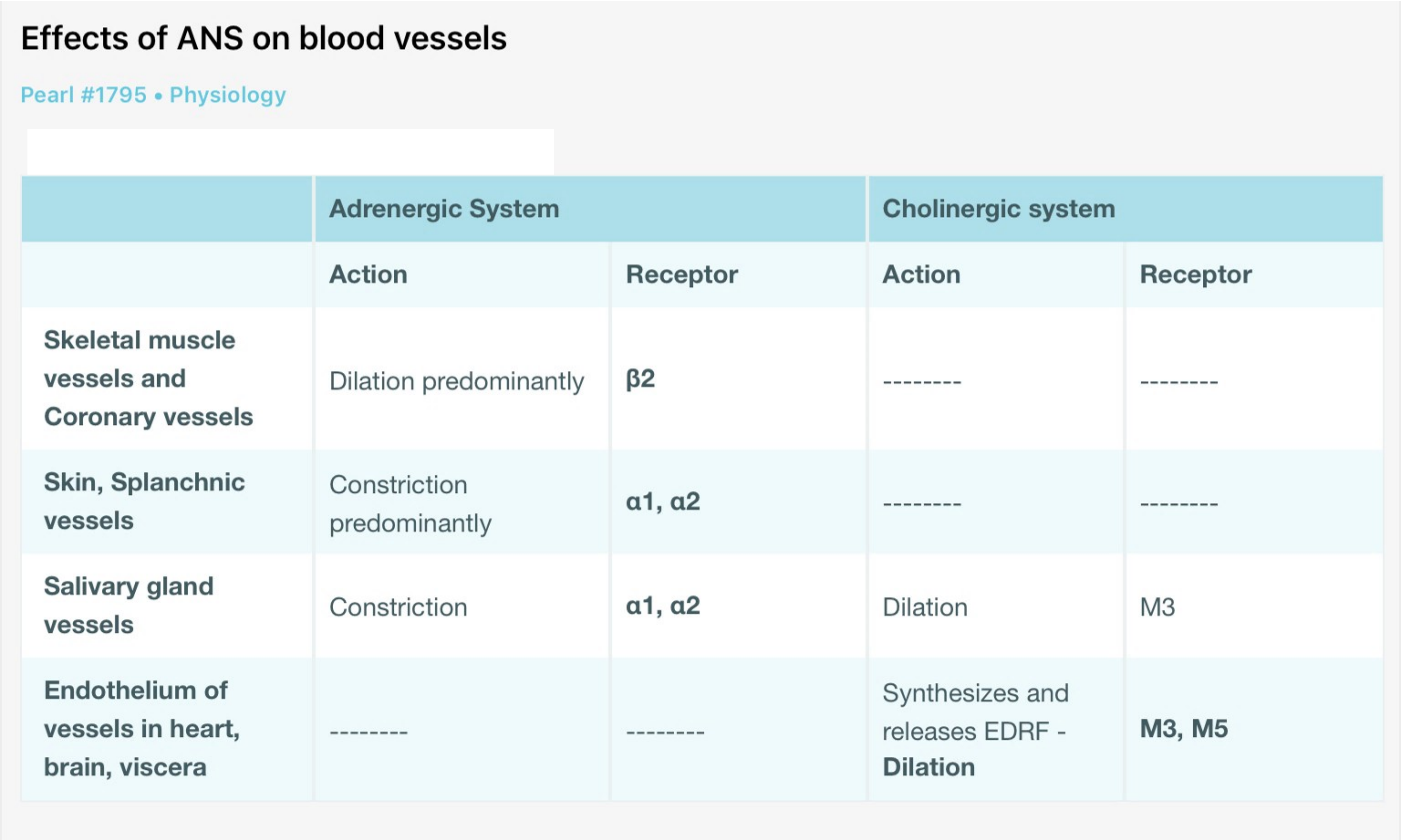
	Adrenergic System	Adrenergic System	Cholinergic System	Cholinergic System
	Action	Receptor	Action	Receptor
Bladder wall - Detrusor	**Relaxation** - Storage	β2	**Contraction** - Expulsion	**M3**
Trigone, Sphincter	**Contraction** - Storage	**α1**	**Relaxation** - Expulsion	**M3**
Pregnant uterus	**Relaxation**	β2	------	**------**
	Contraction	**α1**	Contraction	**M3**
Penis	Ejaculation	**α1**	Erection	**M3**



Effects of ANS in the GI tract

Pearl #1796 • Physiology

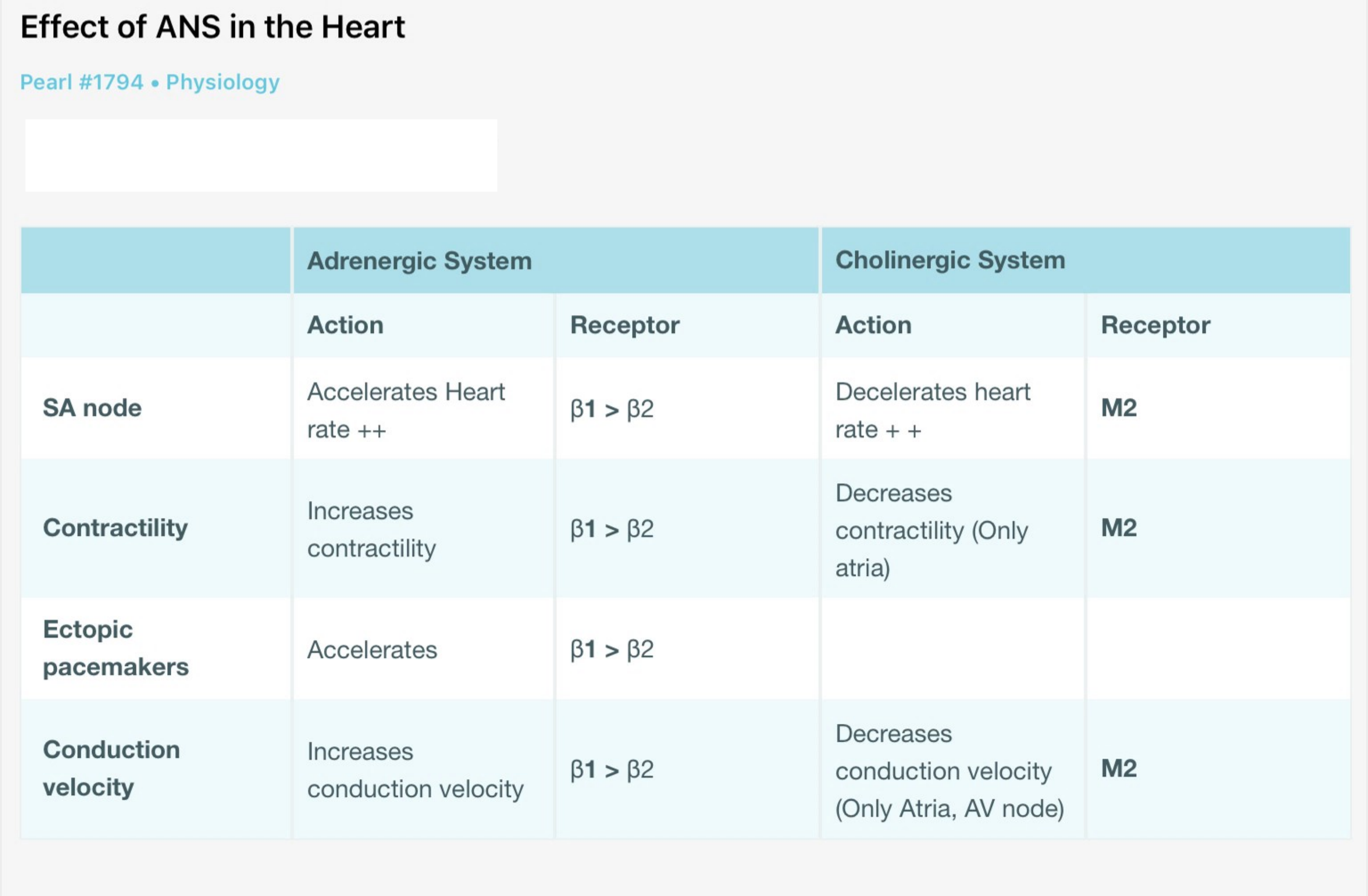
	Adrenergic System		Cholinergic system	
	Action	Receptor	Action	Receptor
Motility	Decreased	α1, α2, β2	Increased	M3
Sphincter	Contraction	α1	Relaxation	M3
Secretions	Inhibition	α2	Increased	M3



Effects of ANS on blood vessels

Pearl #1795 • Physiology

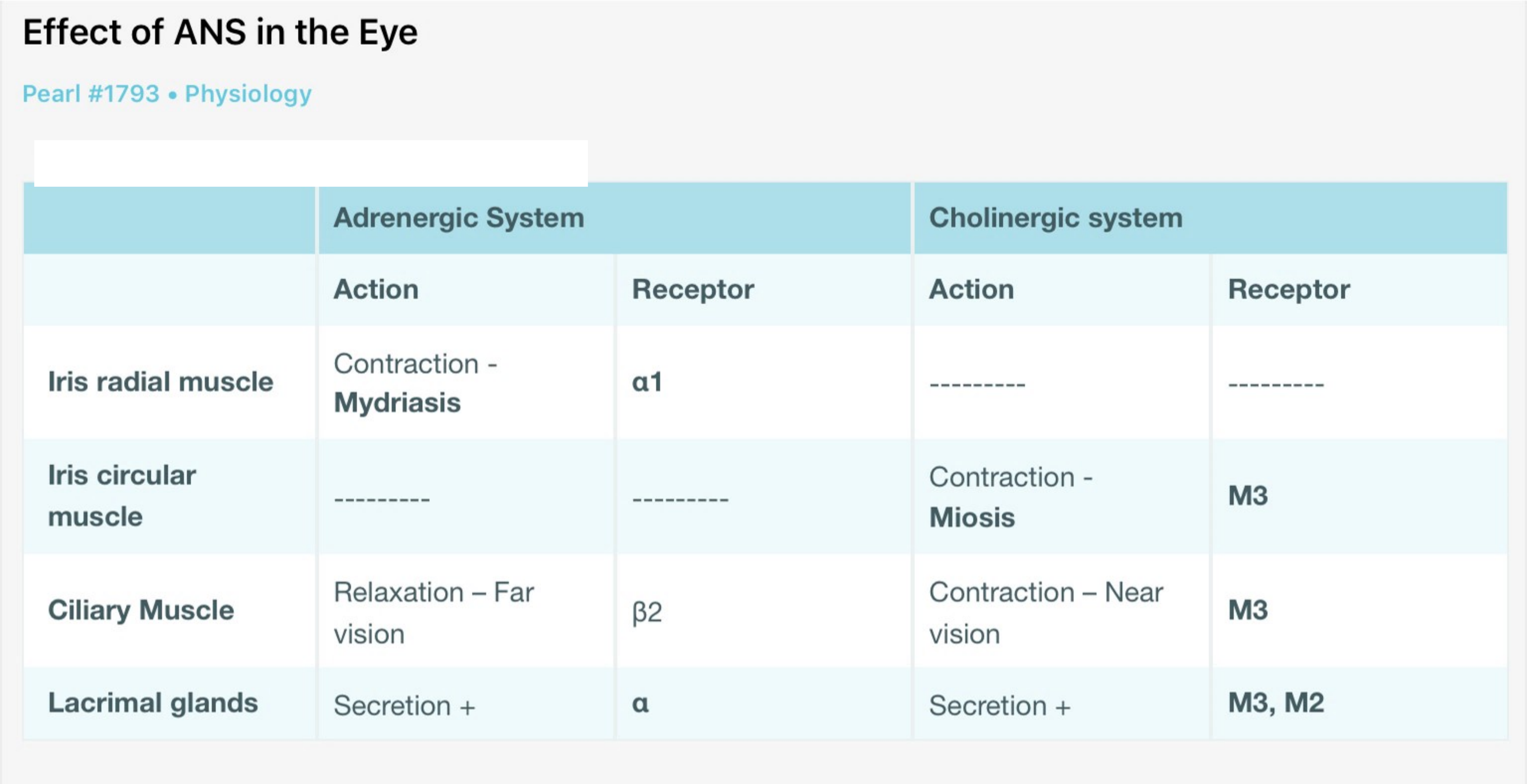
	Adrenergic System		Cholinergic system	
	Action	**Receptor**	**Action**	**Receptor**
Skeletal muscle vessels and Coronary vessels	Dilation predominantly	**β2**	--------	--------
Skin, Splanchnic vessels	Constriction predominantly	**α1, α2**	--------	--------
Salivary gland vessels	Constriction	**α1, α2**	Dilation	M3
Endothelium of vessels in heart, brain, viscera	--------	--------	Synthesizes and releases EDRF - **Dilation**	**M3, M5**



Effect of ANS in the Heart

Pearl #1794 • Physiology

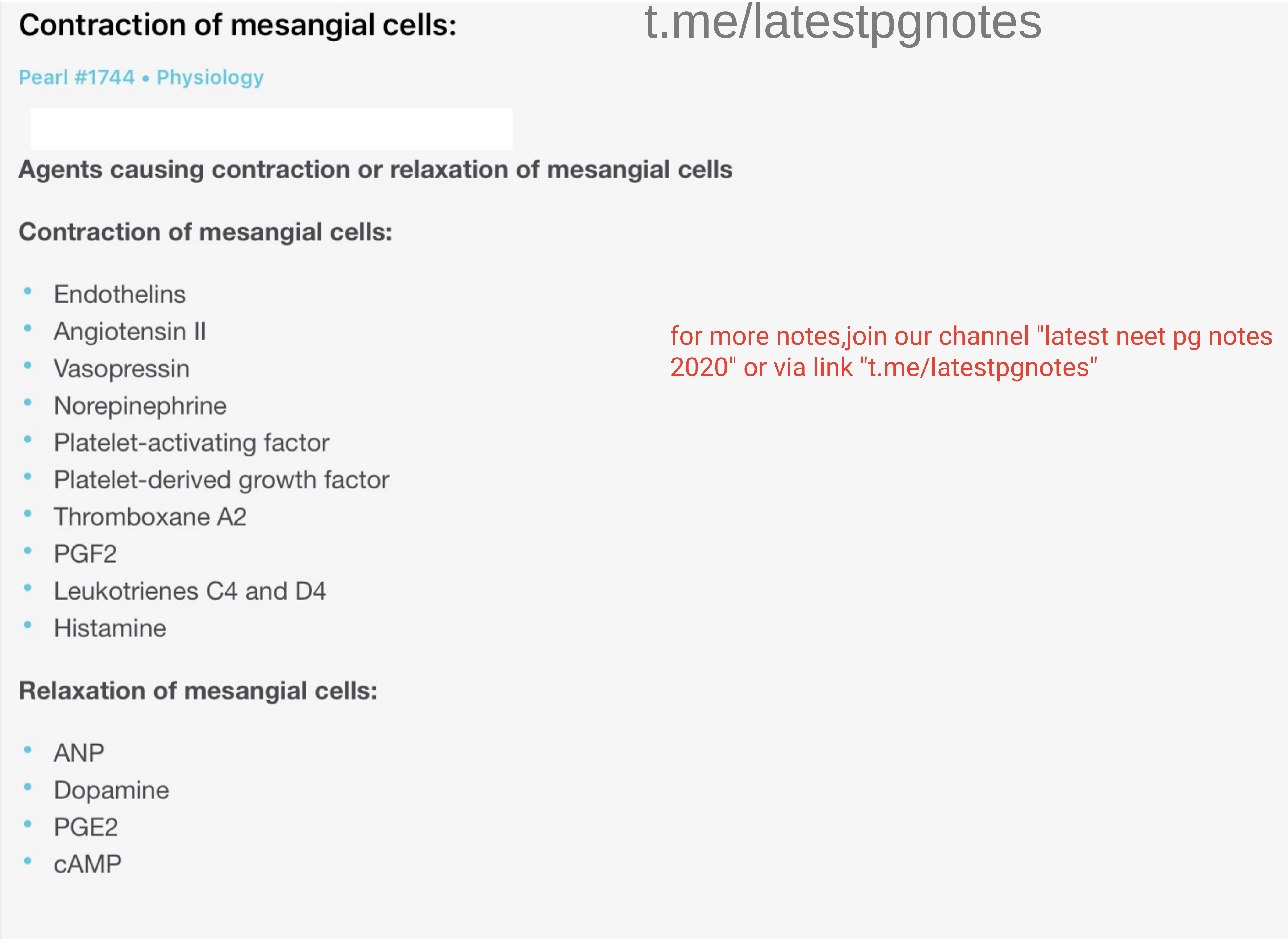
	Adrenergic System		Cholinergic System	
	Action	**Receptor**	**Action**	**Receptor**
SA node	Accelerates Heart rate ++	β1 > β2	Decelerates heart rate + +	**M2**
Contractility	Increases contractility	β1 > β2	Decreases contractility (Only atria)	**M2**
Ectopic pacemakers	Accelerates	β1 > β2		
Conduction velocity	Increases conduction velocity	β1 > β2	Decreases conduction velocity (Only Atria, AV node)	**M2**



Effect of ANS in the Eye

Pearl #1793 • Physiology

	Adrenergic System		Cholinergic system	
	Action	**Receptor**	**Action**	**Receptor**
Iris radial muscle	Contraction - **Mydriasis**	**α1**	---------	---------
Iris circular muscle	---------	---------	Contraction - **Miosis**	**M3**
Ciliary Muscle	Relaxation – Far vision	β2	Contraction – Near vision	**M3**
Lacrimal glands	Secretion +	**α**	Secretion +	**M3, M2**



Contraction of mesangial cells:

Pearl #1744 • Physiology

Agents causing contraction or relaxation of mesangial cells

Contraction of mesangial cells:

- Endothelins
- Angiotensin II
- Vasopressin
- Norepinephrine
- Platelet-activating factor
- Platelet-derived growth factor
- Thromboxane A2
- PGF2
- Leukotrienes C4 and D4
- Histamine

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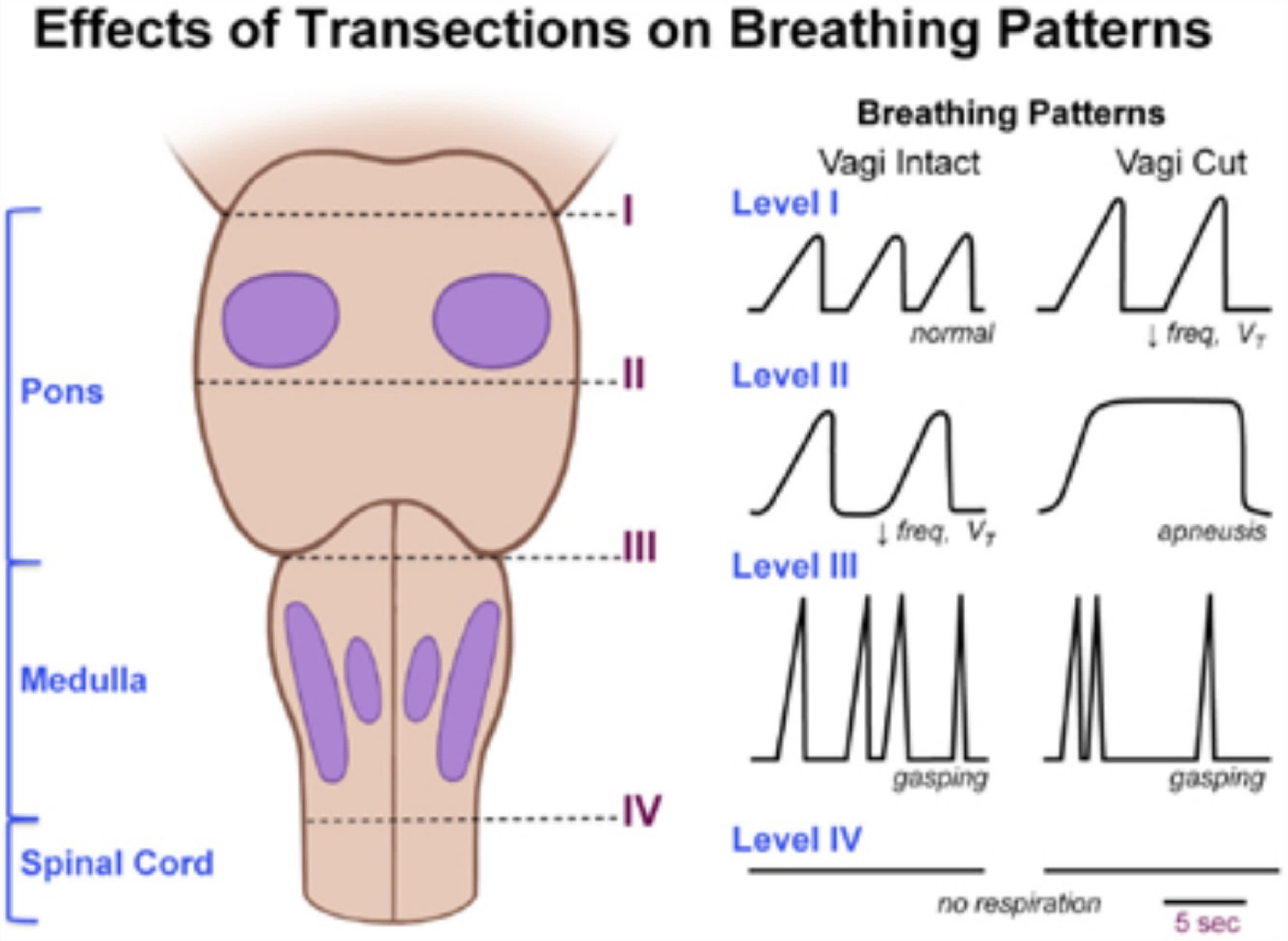
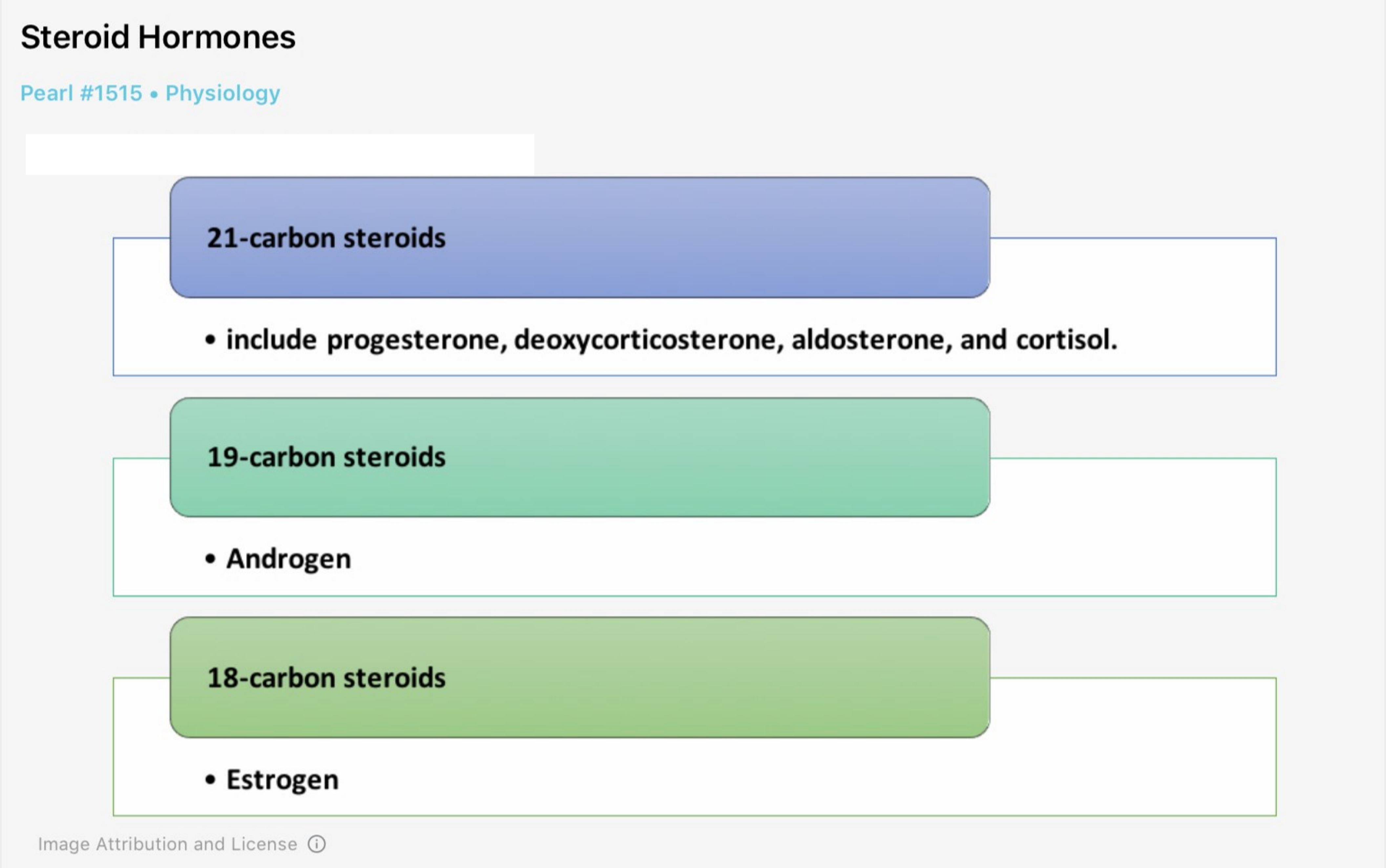
Relaxation of mesangial cells:

- ANP
- Dopamine
- PGE2
- cAMP

Effects of Transection on Breathing patterns :

Pearl #1743 • Physiology





Steroid Hormones

Pearl #1515 • Physiology

21-carbon steroids

- include progesterone, deoxycorticosterone, aldosterone, and cortisol.

19-carbon steroids

- Androgen

18-carbon steroids

- Estrogen

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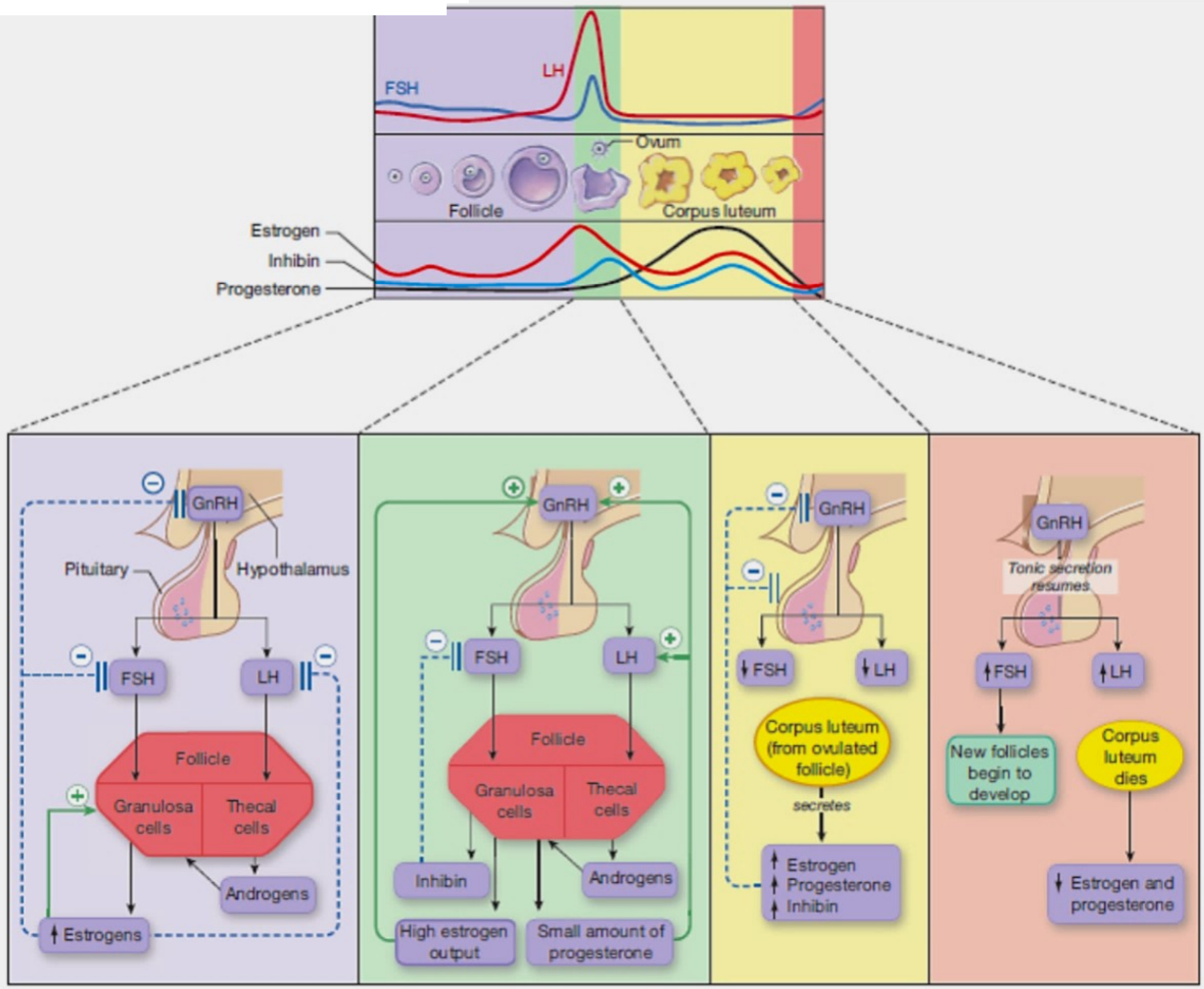
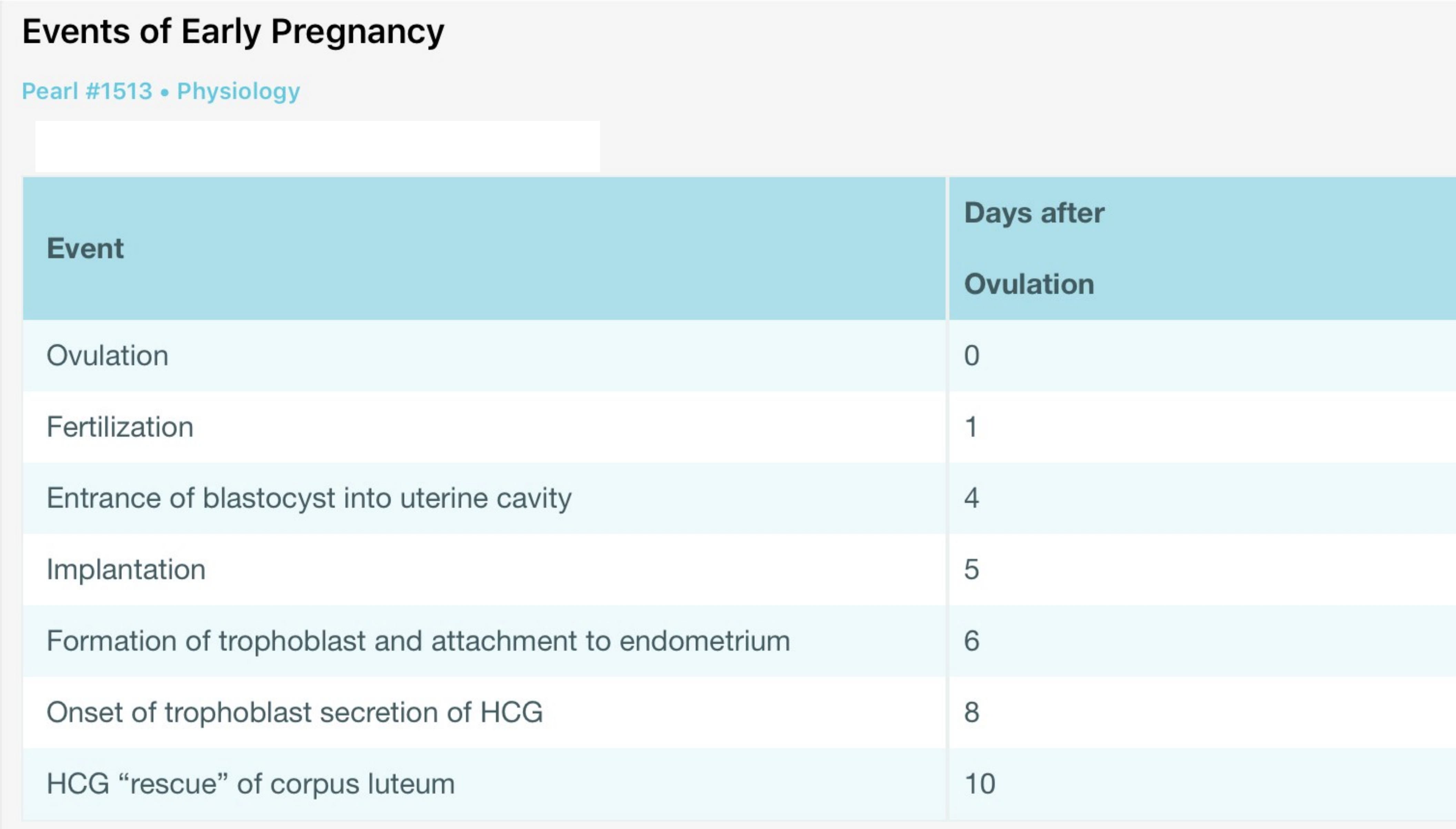
Hormonal Regulation of Menstrual Cycle

Pearl #1514 • Physiology



(a) Early to mid-follicular phase (b) Late follicular phase and ovulation (c) Early to mid-luteal phase (d) Late luteal phase



Events of Early Pregnancy

Pearl #1513 • Physiology

Event	Days after Ovulation
Ovulation	0
Fertilization	1
Entrance of blastocyst into uterine cavity	4
Implantation	5
Formation of trophoblast and attachment to endometrium	6
Onset of trophoblast secretion of HCG	8
HCG “rescue” of corpus luteum	10

Composition of Human Semen

Pearl #1511 • Physiology

Color: white, opalescent

Sperm count: Average about **100million/mL**, with <20% abnormal form

pH:7.35-7.50

Specific gravity: 1.028

Components from seminal vesicles (contributes **60% of total volume)**

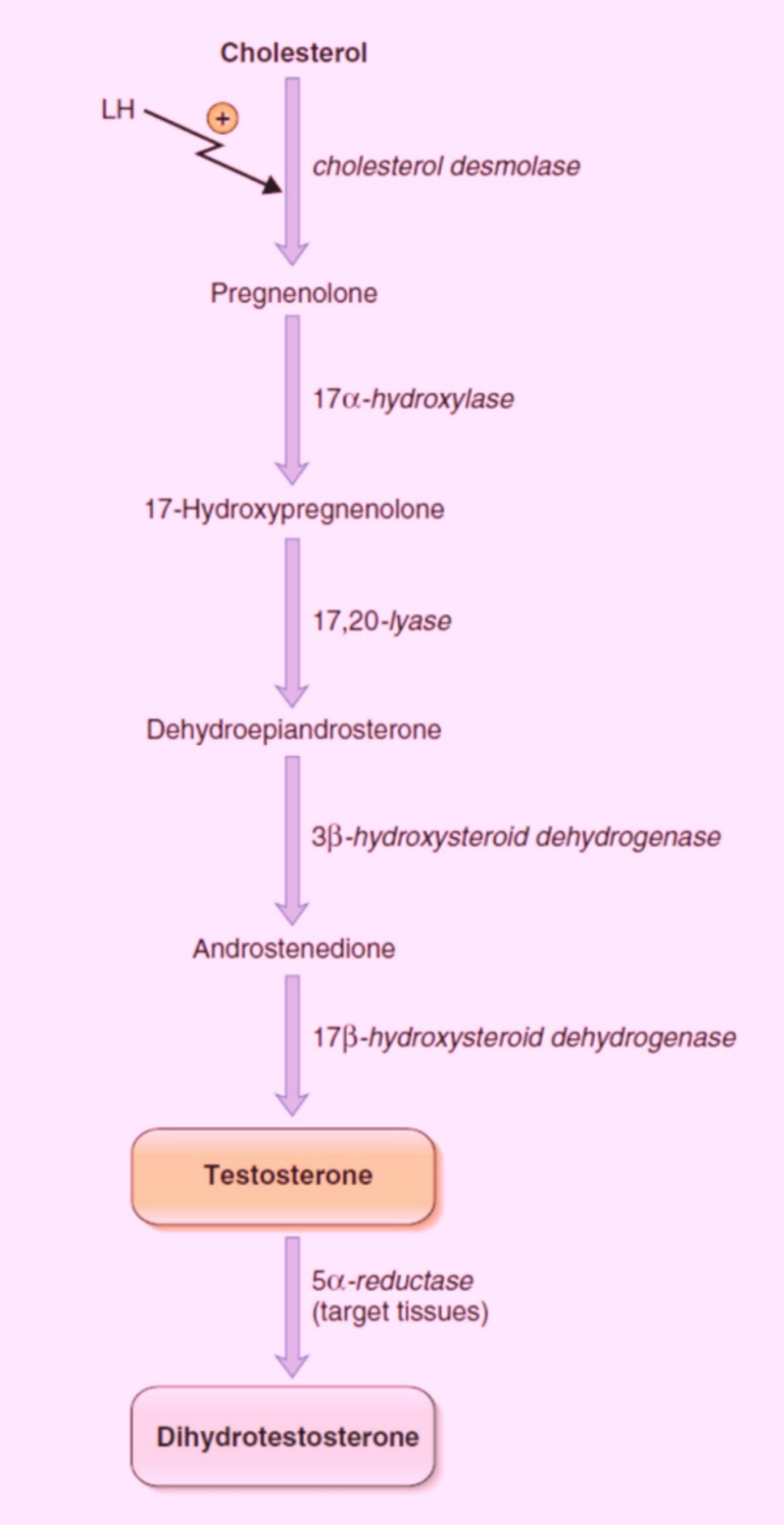
- Fructose
- Phosphorylcholine
- Ergothioneine
- Ascorbic acid
- Flavins
- Prostaglandins

Components from prostrate (contributes **20% of total volume)**

- Spermine
- Citric acid
- Cholesterol, phospholipids
- Fibrinolysin, fibrinogenase
- Zinc
- Acid phosphatase

Buffers

- Phosphate
- Bicarbonate
- Hyaluronidase
- Magnesium



Cholesterol

LH ⊕

cholesterol desmolase

Pregnenolone

17α-*hydroxylase*

17-Hydroxypregnenolone

17,20-*lyase*

Dehydroepiandrosterone

3β-*hydroxysteroid dehydrogenase*

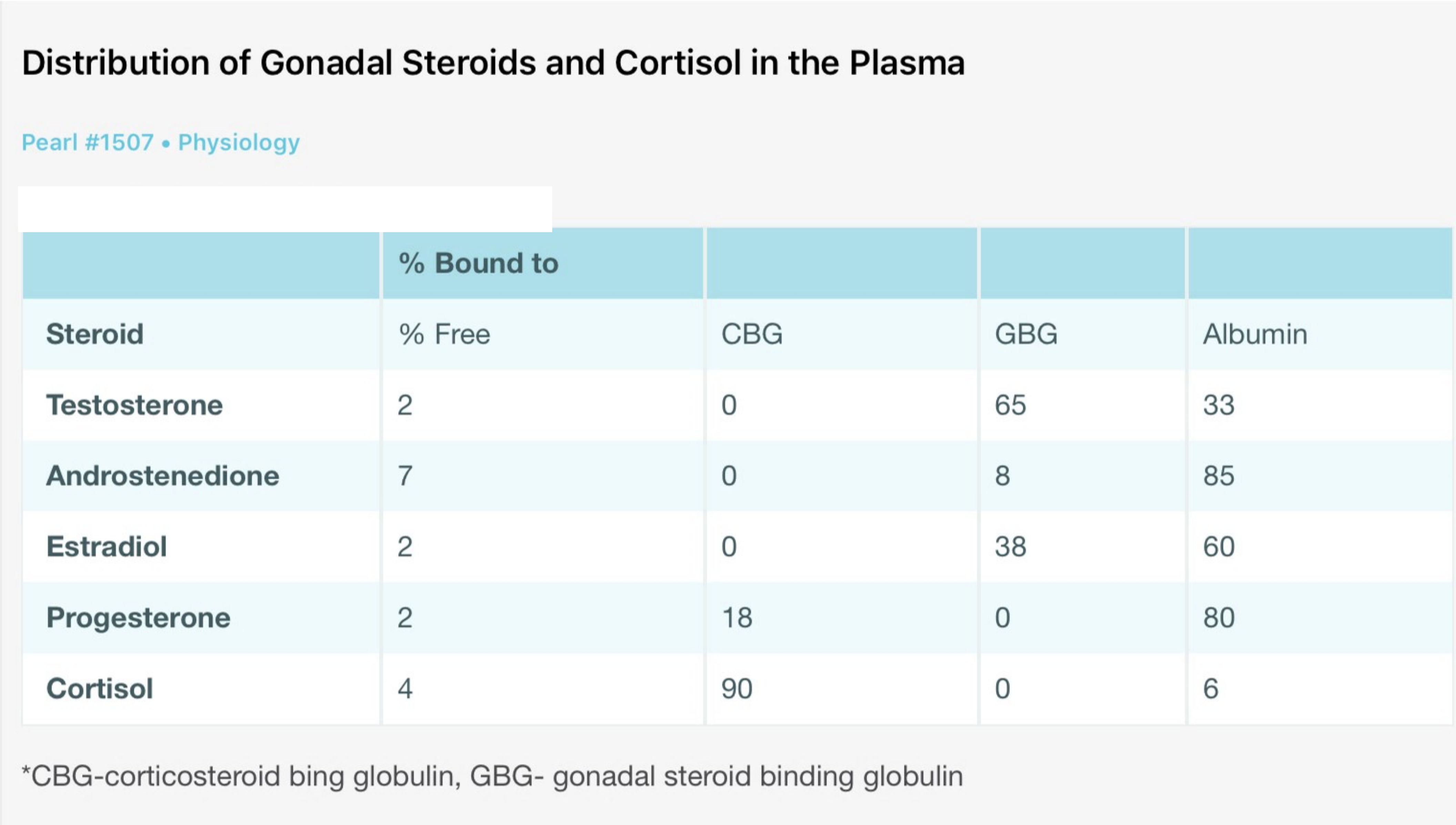
Androstenedione

17β-*hydroxysteroid dehydrogenase*

Testosterone

5α-*reductase*
(target tissues)

Dihydrotestosterone

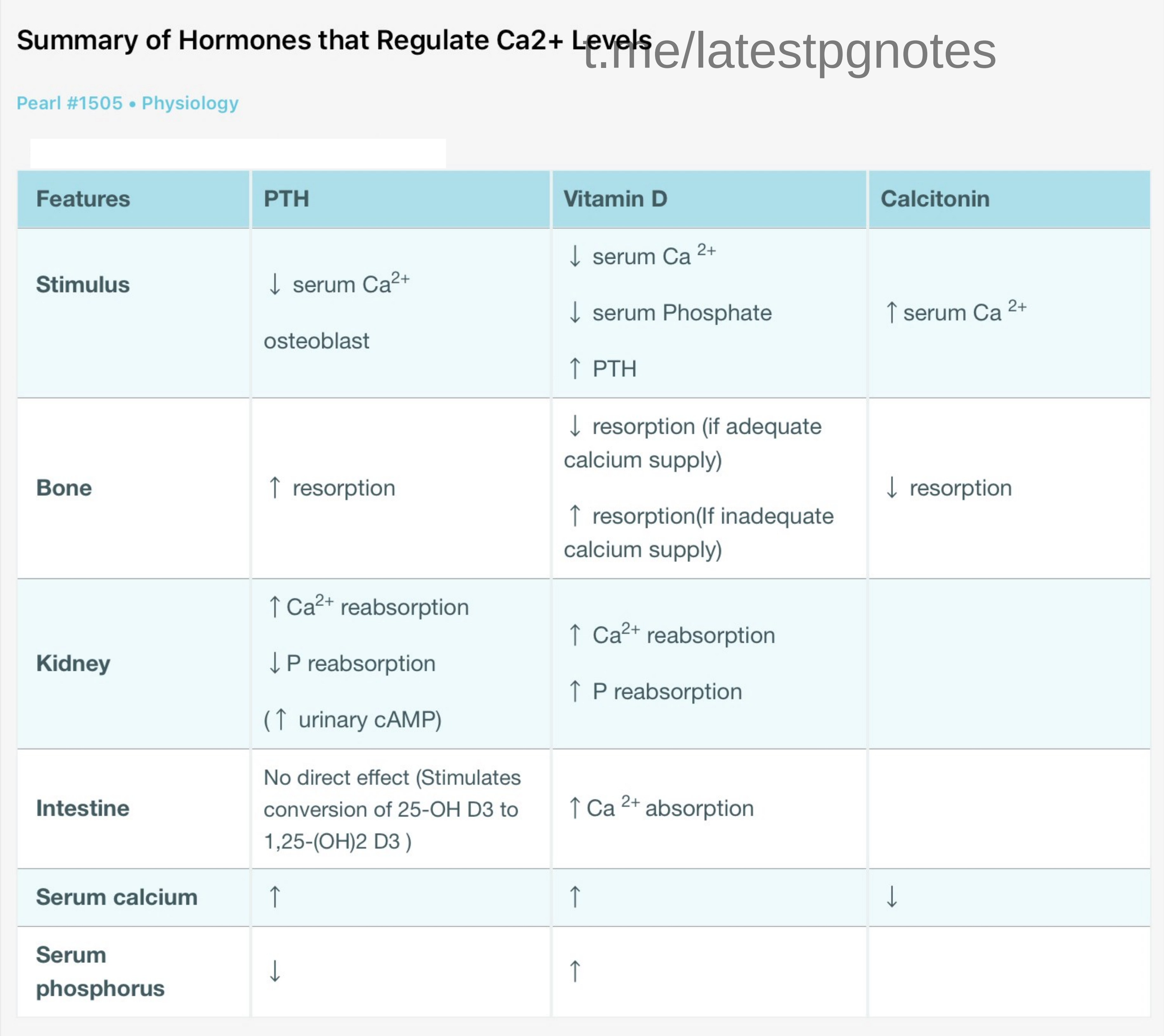


Distribution of Gonadal Steroids and Cortisol in the Plasma

Pearl #1507 • Physiology

	% Bound to			
Steroid	% Free	CBG	GBG	Albumin
Testosterone	2	0	65	33
Androstenedione	7	0	8	85
Estradiol	2	0	38	60
Progesterone	2	18	0	80
Cortisol	4	90	0	6

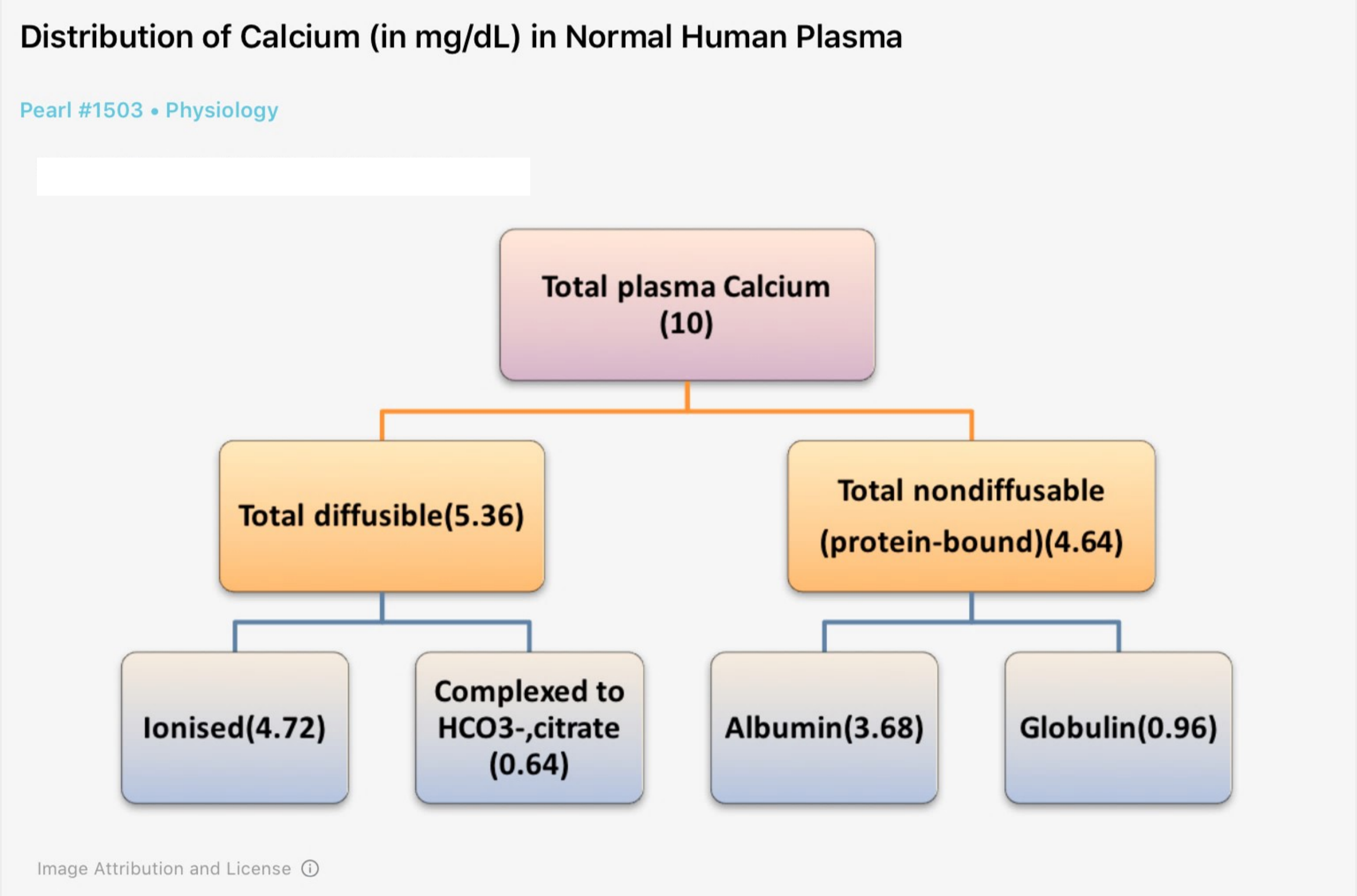
*CBG-corticosteroid bing globulin, GBG- gonadal steroid binding globulin



Summary of Hormones that Regulate Ca2+ Levels

Pearl #1505 • Physiology

Features	PTH	Vitamin D	Calcitonin
Stimulus	↓ serum Ca^{2+} osteoblast	↓ serum Ca $^{2+}$ ↓ serum Phosphate ↑ PTH	↑ serum Ca $^{2+}$
Bone	↑ resorption	↓ resorption (if adequate calcium supply) ↑ resorption(If inadequate calcium supply)	↓ resorption
Kidney	↑ Ca^{2+} reabsorption ↓ P reabsorption (↑ urinary cAMP)	↑ Ca^{2+} reabsorption ↑ P reabsorption	
Intestine	No direct effect (Stimulates conversion of 25-OH D3 to 1,25-(OH)2 D3)	↑ Ca $^{2+}$ absorption	
Serum calcium	↑	↑	↓
Serum phosphorus	↓	↑	



Distribution of Calcium (in mg/dL) in Normal Human Plasma

Pearl #1503 • Physiology

Total plasma Calcium (10)
Total diffusible(5.36)
Total nondiffusable (protein-bound)(4.64)
Ionised(4.72)
Complexed to HCO3-,citrate (0.64)
Albumin(3.68)
Globulin(0.96)

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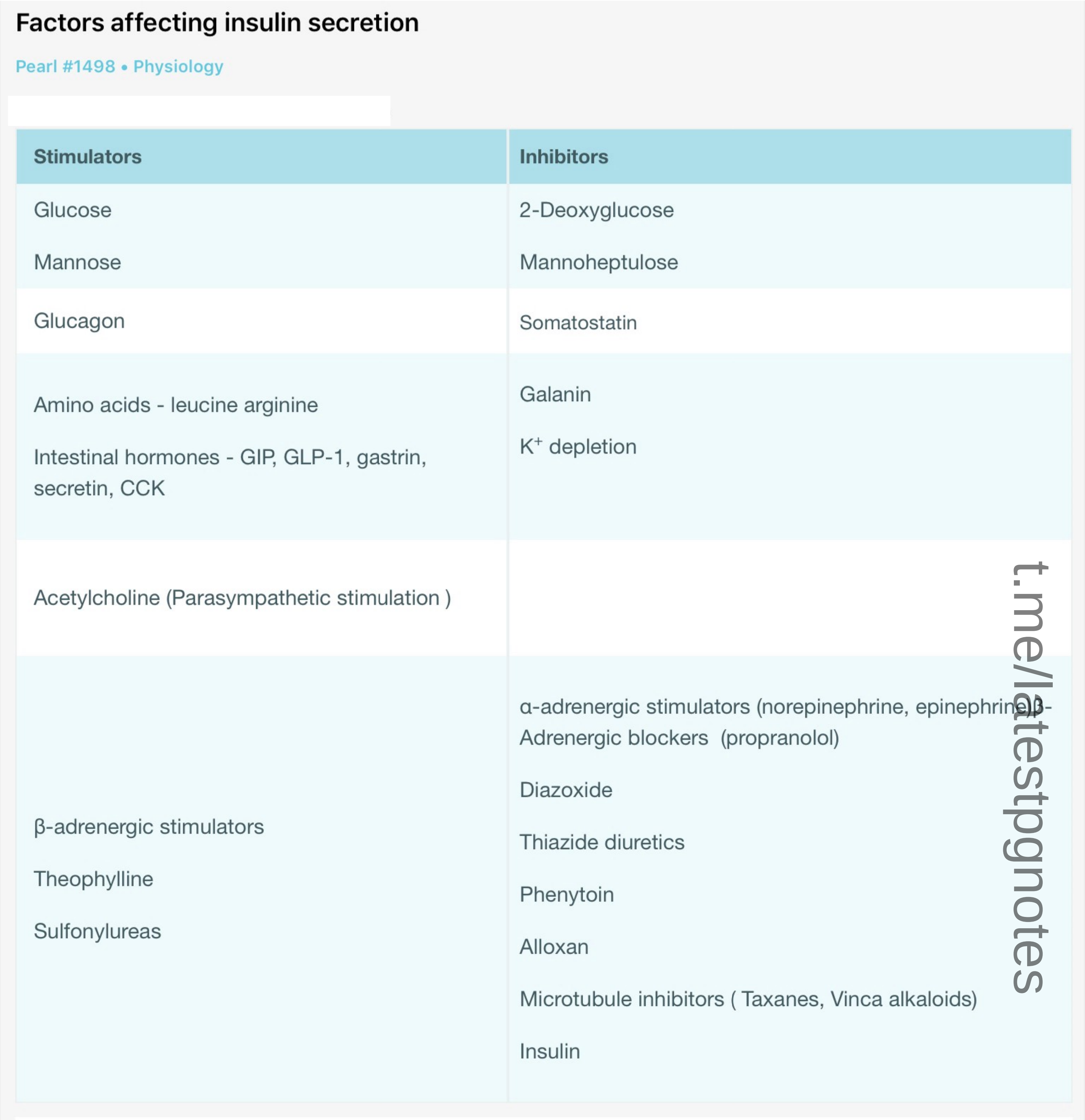
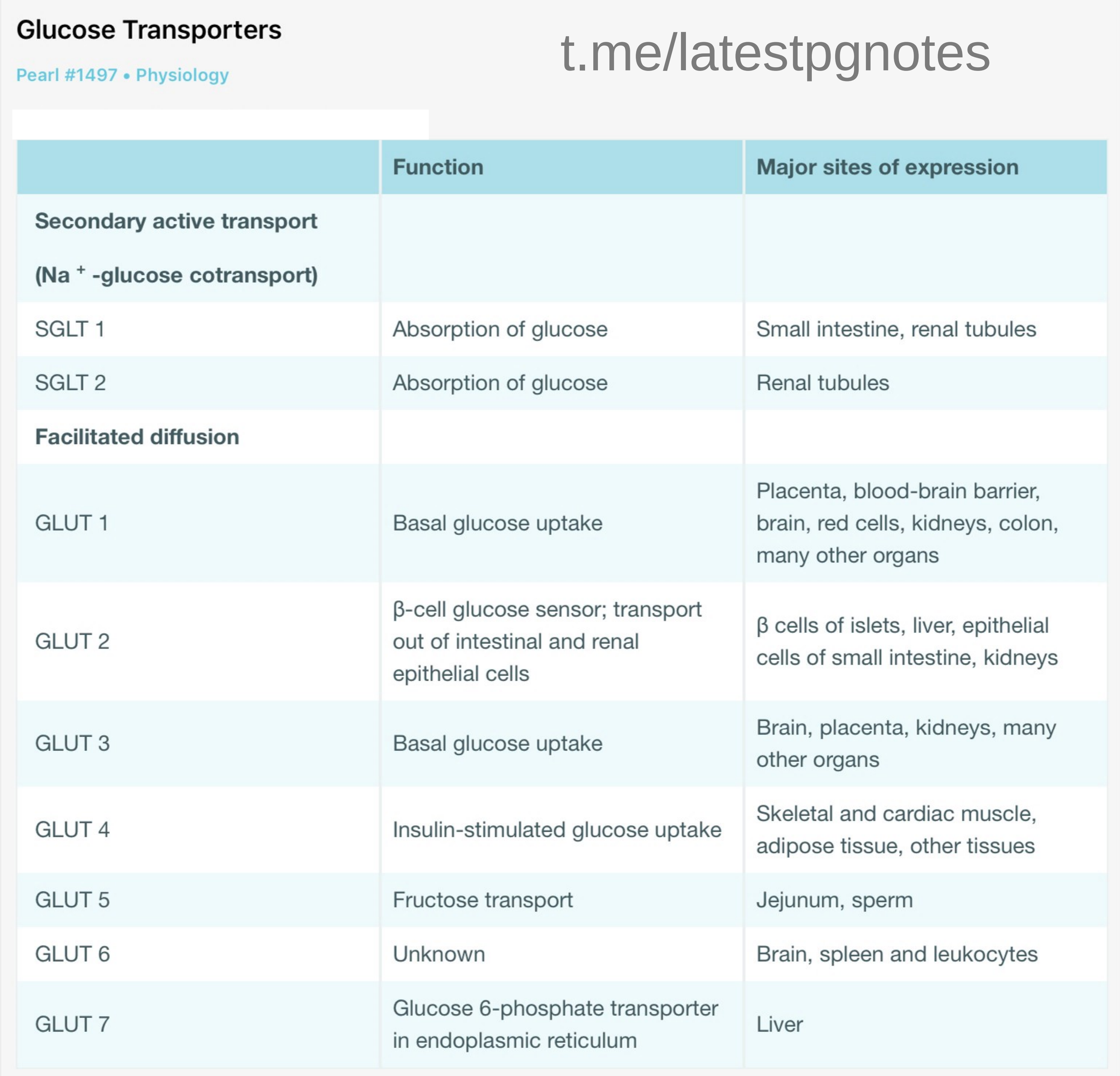


Factors affecting insulin secretion

Pearl #1498 • Physiology

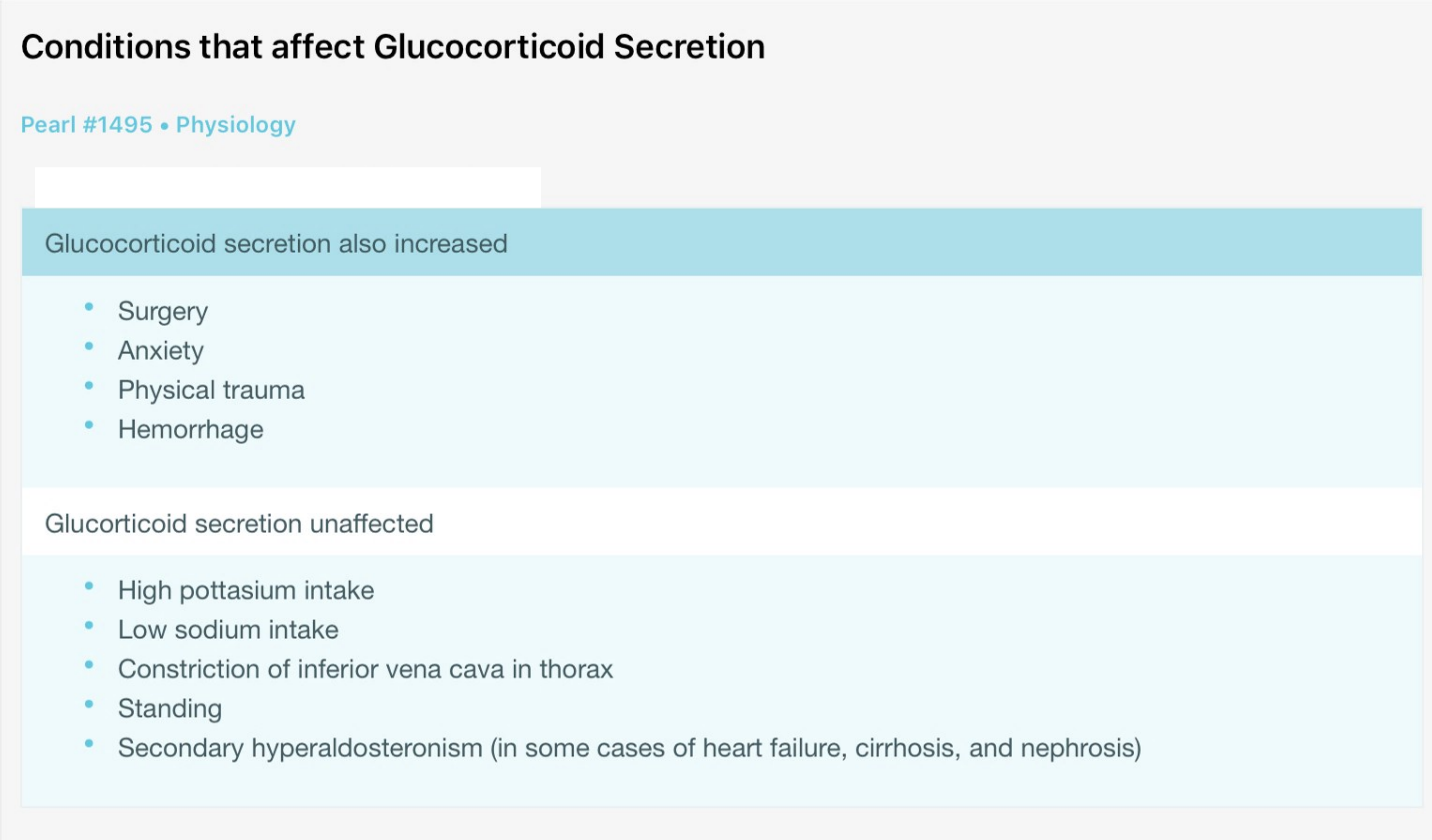
Stimulators	Inhibitors
Glucose	2-Deoxyglucose
Mannose	Mannoheptulose
Glucagon	Somatostatin
Amino acids - leucine arginine	Galanin
Intestinal hormones - GIP, GLP-1, gastrin, secretin, CCK	K^+ depletion
Acetylcholine (Parasympathetic stimulation)	
β-adrenergic stimulators Theophylline Sulfonylureas	α-adrenergic stimulators (norepinephrine, epinephrine)β-Adrenergic blockers (propranolol) Diazoxide Thiazide diuretics Phenytoin Alloxan Microtubule inhibitors (Taxanes, Vinca alkaloids) Insulin



Glucose Transporters

Pearl #1497 • Physiology

	Function	Major sites of expression
Secondary active transport **(Na $^+$ -glucose cotransport)**		
SGLT 1	Absorption of glucose	Small intestine, renal tubules
SGLT 2	Absorption of glucose	Renal tubules
Facilitated diffusion		
GLUT 1	Basal glucose uptake	Placenta, blood-brain barrier, brain, red cells, kidneys, colon, many other organs
GLUT 2	β-cell glucose sensor; transport out of intestinal and renal epithelial cells	β cells of islets, liver, epithelial cells of small intestine, kidneys
GLUT 3	Basal glucose uptake	Brain, placenta, kidneys, many other organs
GLUT 4	Insulin-stimulated glucose uptake	Skeletal and cardiac muscle, adipose tissue, other tissues
GLUT 5	Fructose transport	Jejunum, sperm
GLUT 6	Unknown	Brain, spleen and leukocytes
GLUT 7	Glucose 6-phosphate transporter in endoplasmic reticulum	Liver



Conditions that affect Glucocorticoid Secretion

Pearl #1495 • Physiology

Glucocorticoid secretion also increased

- Surgery
- Anxiety
- Physical trauma
- Hemorrhage

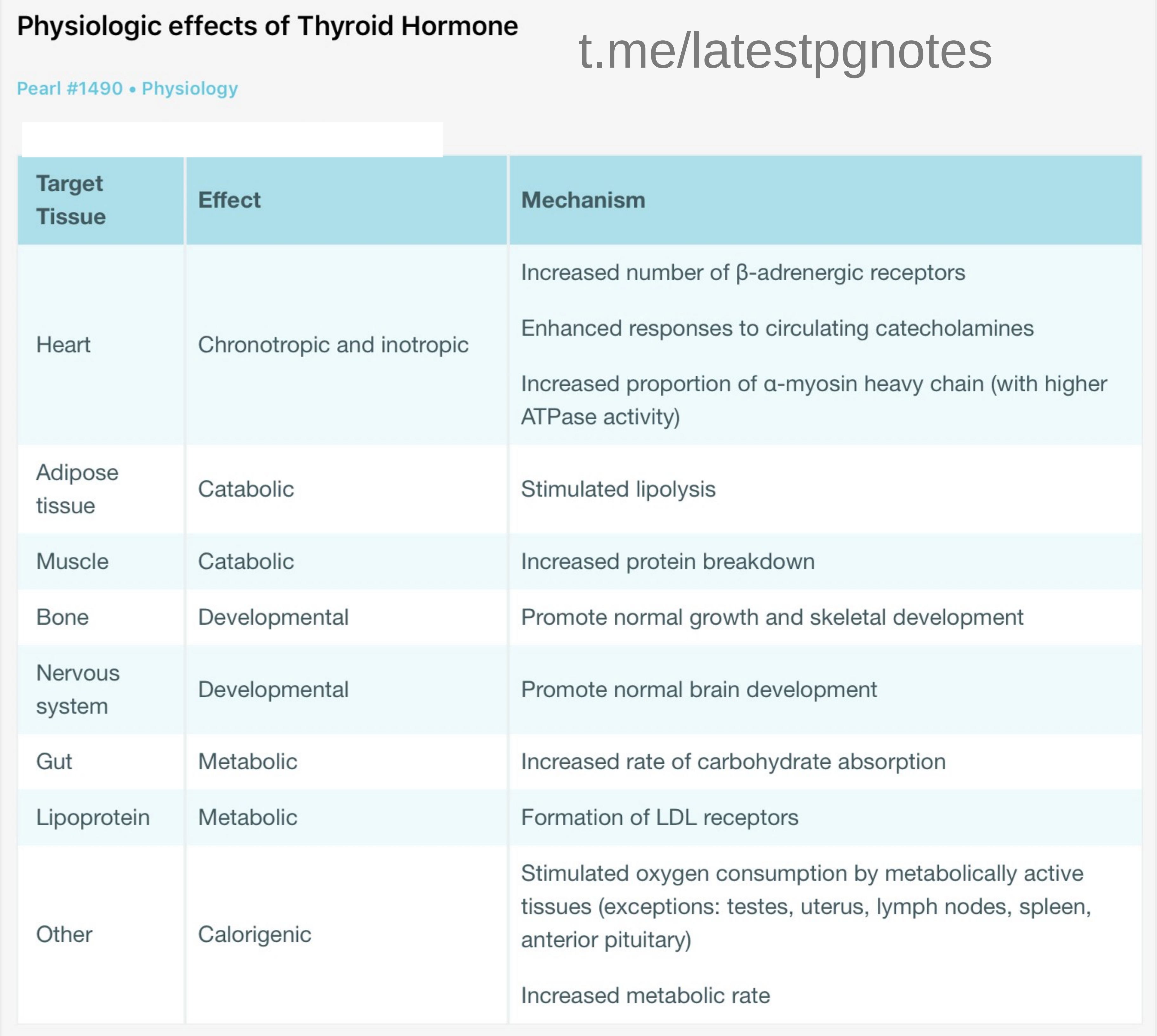
Glucorticoid secretion unaffected

- High pottasium intake
- Low sodium intake
- Constriction of inferior vena cava in thorax
- Standing
- Secondary hyperaldosteronism (in some cases of heart failure, cirrhosis, and nephrosis)

Secretion of Adrenal Hormones by the different Zones of the Adrenal Cortex and Adrenal Medulla

Pearl #1494 • Physiology

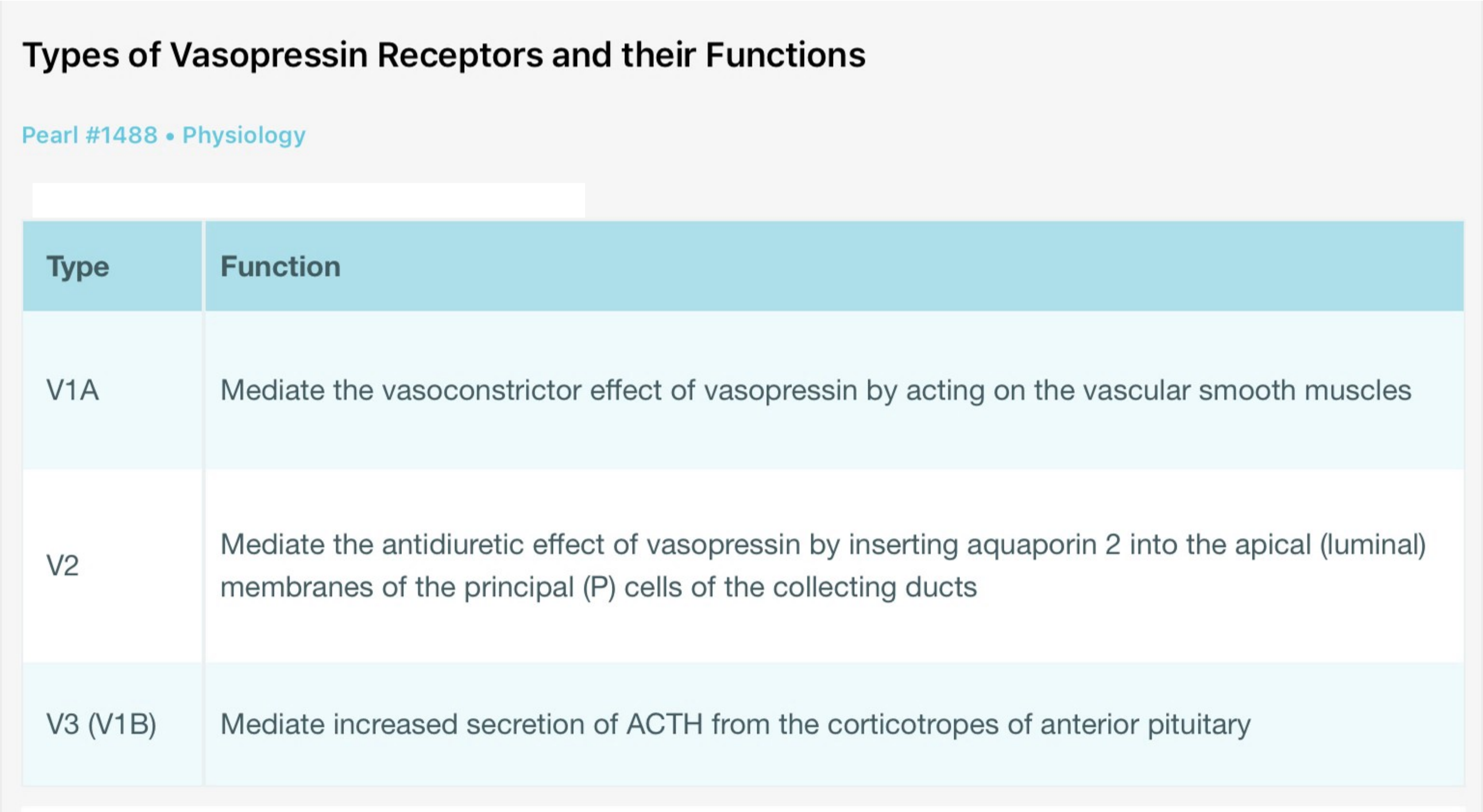
Adrenal Cortex	Adrenal Medulla
Zona glomerulosa(15%) Mineralocorticoids Aldosterone Deoxycorticosterone	**Norepinephrine** **Epinephrine** **Dopamine**
Zona fasiculata (50%) Glucocorticoids Cortisol Corticosterone	
Zona reticularis(7%) Androgens: • DHEA • Androstenedione	



Physiologic effects of Thyroid Hormone

Pearl #1490 • Physiology

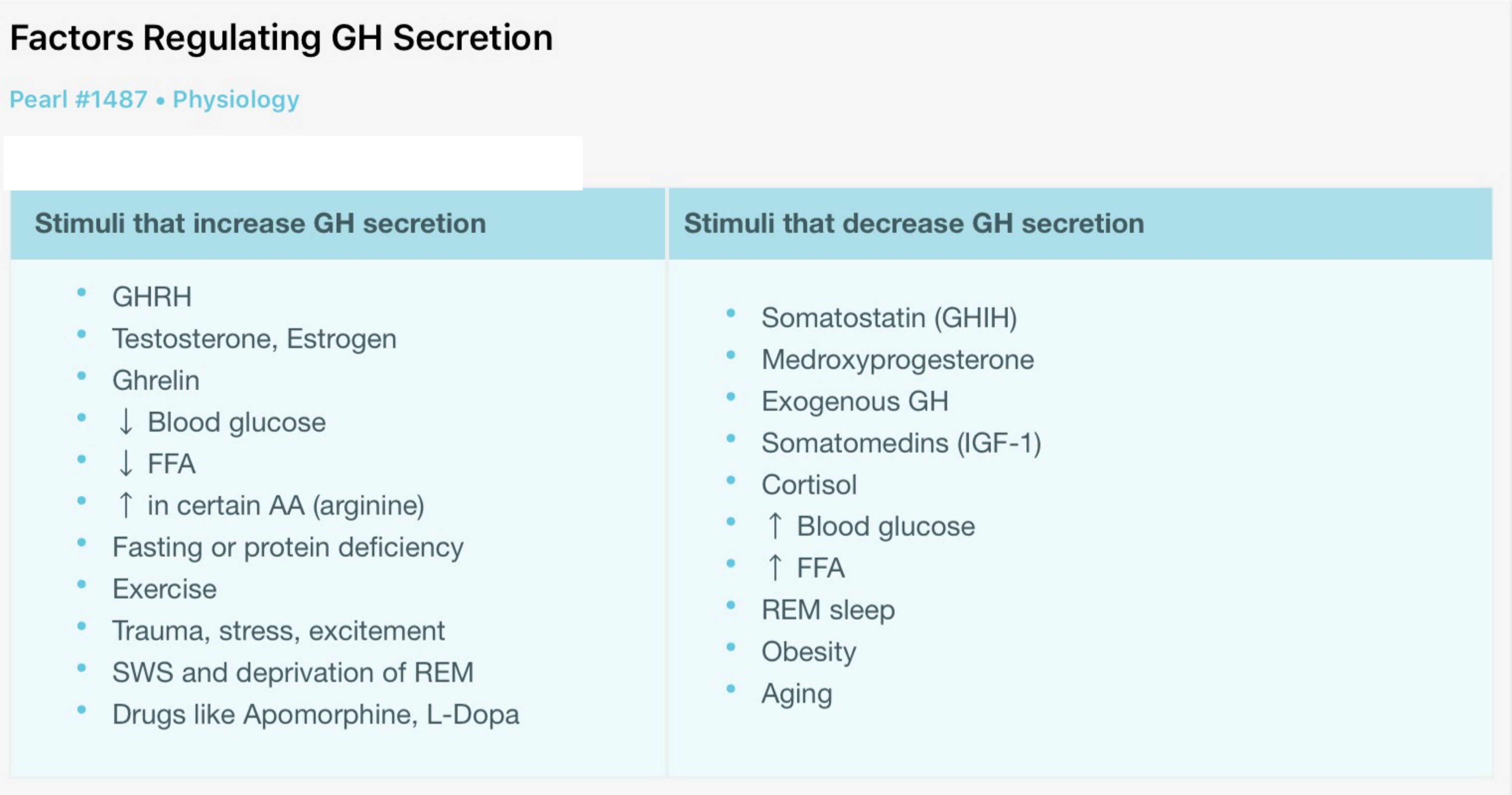
Target Tissue	Effect	Mechanism
Heart	Chronotropic and inotropic	Increased number of β-adrenergic receptors Enhanced responses to circulating catecholamines Increased proportion of α-myosin heavy chain (with higher ATPase activity)
Adipose tissue	Catabolic	Stimulated lipolysis
Muscle	Catabolic	Increased protein breakdown
Bone	Developmental	Promote normal growth and skeletal development
Nervous system	Developmental	Promote normal brain development
Gut	Metabolic	Increased rate of carbohydrate absorption
Lipoprotein	Metabolic	Formation of LDL receptors
Other	Calorigenic	Stimulated oxygen consumption by metabolically active tissues (exceptions: testes, uterus, lymph nodes, spleen, anterior pituitary) Increased metabolic rate



Types of Vasopressin Receptors and their Functions

Pearl #1488 • Physiology

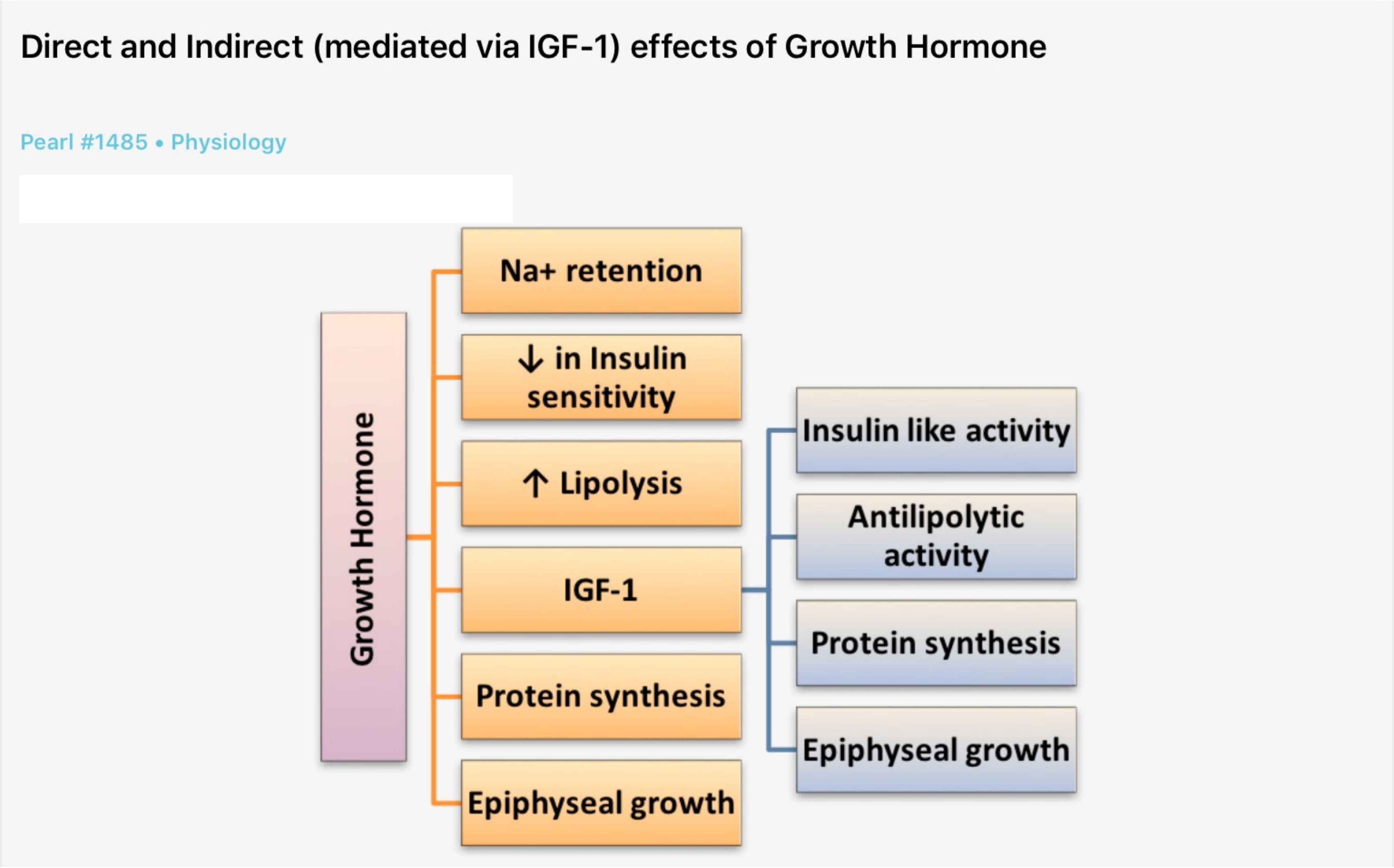
Type	Function
V1A	Mediate the vasoconstrictor effect of vasopressin by acting on the vascular smooth muscles
V2	Mediate the antidiuretic effect of vasopressin by inserting aquaporin 2 into the apical (luminal) membranes of the principal (P) cells of the collecting ducts
V3 (V1B)	Mediate increased secretion of ACTH from the corticotropes of anterior pituitary



Factors Regulating GH Secretion

Pearl #1487 • Physiology

Stimuli that increase GH secretion	Stimuli that decrease GH secretion
GHRH	Somatostatin (GHIH)
Testosterone, Estrogen	Medroxyprogesterone
Ghrelin	Exogenous GH
↓ Blood glucose	Somatomedins (IGF-1)
↓ FFA	Cortisol
↑ in certain AA (arginine)	↑ Blood glucose
Fasting or protein deficiency	↑ FFA
Exercise	REM sleep
Trauma, stress, excitement	Obesity
SWS and deprivation of REM	Aging
Drugs like Apomorphine, L-Dopa	



Direct and Indirect (mediated via IGF-1) effects of Growth Hormone

Pearl #1485 • Physiology

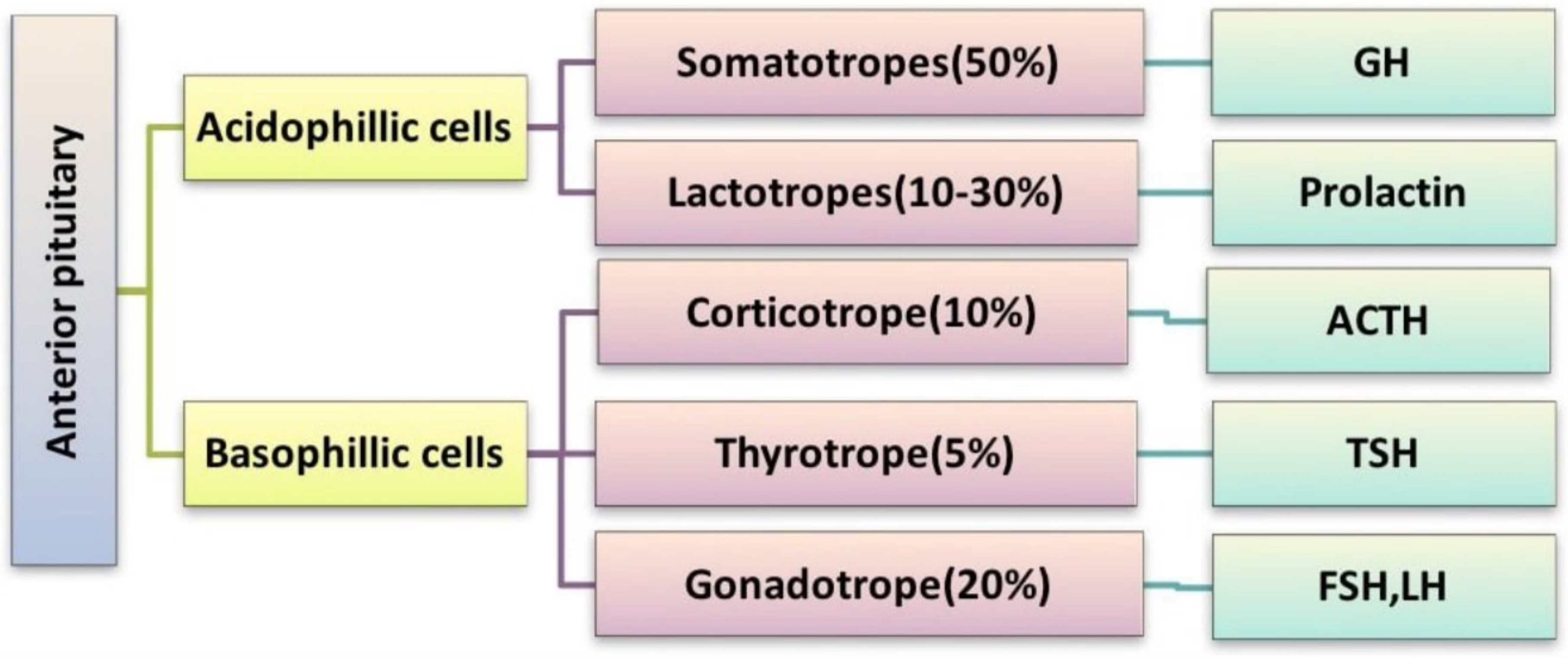
Factors affecting Prolactin Secretion

Pearl #1484 • Physiology

Increased Prolactin Secretion	Decreased Prolactin Secretion
Sleep	Dopamine
Stress	L-Dopa
Strenuous exercise	Apomorphine
Sexual intercourse in women	Bromocriptine and related ergot derivatives
Pregnancy	
Nursing	
Breast stimulation in non-lactating women	
Estrogen	
Hypothyroidism	
TRH	
Opioids	
Phenothiazines, butyrophenones	

Cells of Anterior Pituitary

Pearl #1483 • Physiology



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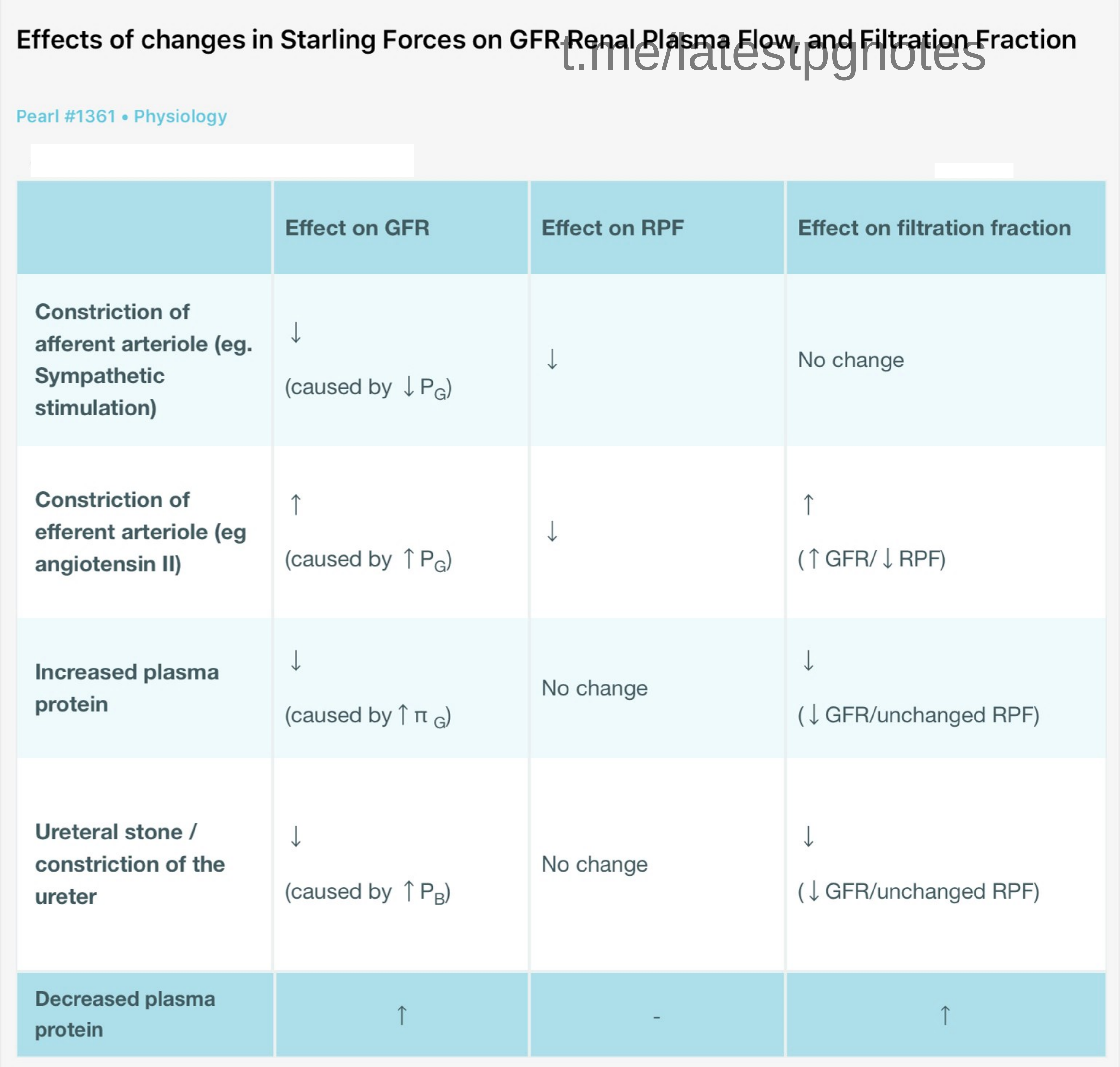


Effects of changes in Starling Forces on GFR Renal Plasma Flow, and Filtration Fraction

Pearl #1361 • Physiology

	Effect on GFR	Effect on RPF	Effect on filtration fraction
Constriction of afferent arteriole (eg. Sympathetic stimulation)	↓ (caused by ↓ P_G)	↓	No change
Constriction of efferent arteriole (eg angiotensin II)	↑ (caused by ↑ P_G)	↓	↑ (↑ GFR/ ↓ RPF)
Increased plasma protein	↓ (caused by ↑ π_G)	No change	↓ (↓ GFR/unchanged RPF)
Ureteral stone / constriction of the ureter	↓ (caused by ↑ P_B)	No change	↓ (↓ GFR/unchanged RPF)
Decreased plasma protein	↑	-	↑

Factors Affecting GFR

Pearl #1360 • Physiology

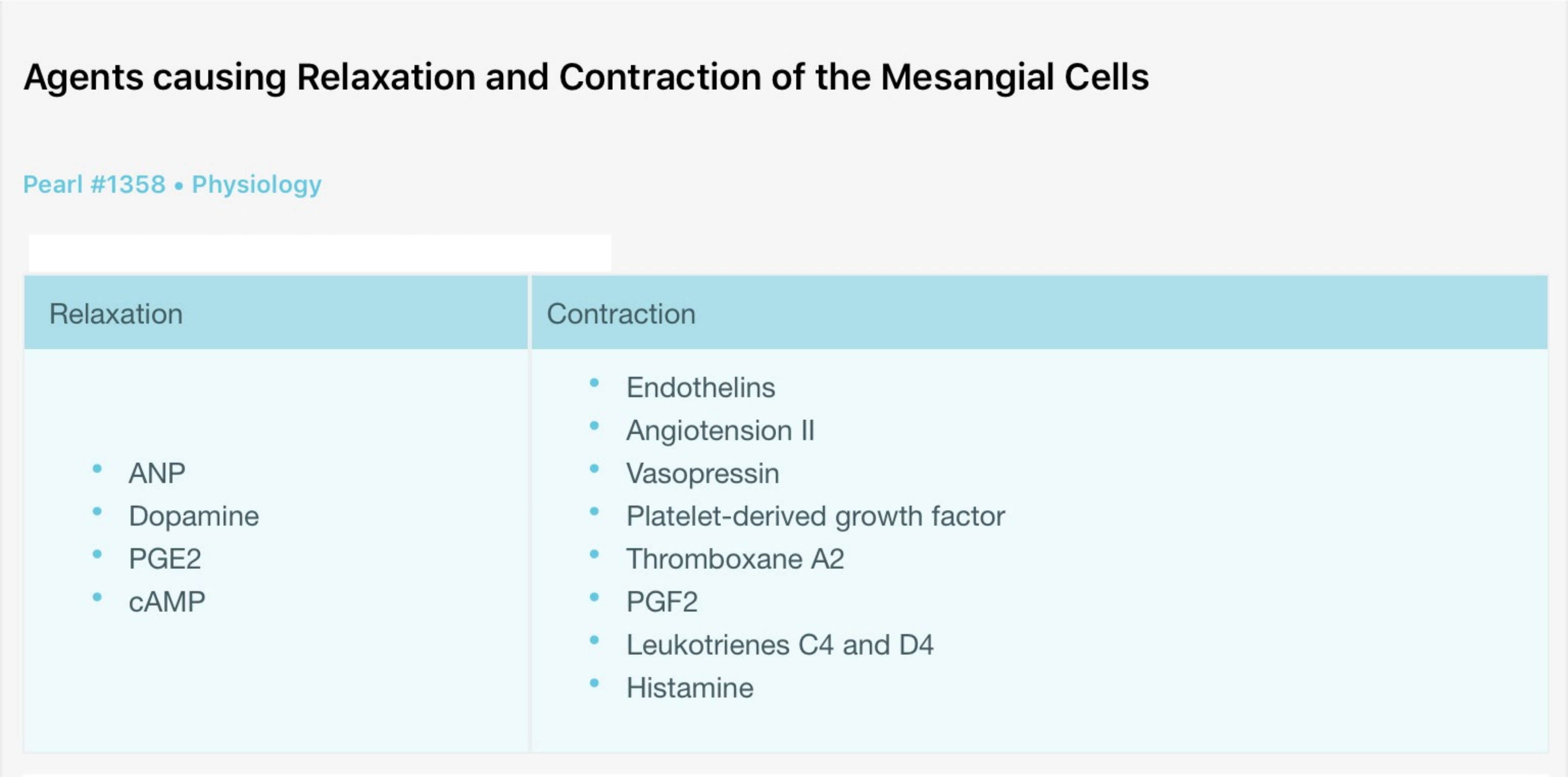
Determinants	Physiological/Pathophysiological Causes
↓ K_f (filtration coefficient)→ ↓ GFR	Renal disease, diabetes mellitus, hypertension
↑ P_B → ↓ GFR	Urinary tract obstruction (e.g., kidney stones)
↑ π_G → ↓ GFR	↓ Renal blood flow increased plasma proteins
↓ P_G → ↓ GFR a) ↑ afferent arteriolar resistance (R_A)→ ↓ P_G	↑ Sympathetic activity, (e.g., norepinephrine, endothelin)
b) ↓ systemic arterial pressure(A_P)→ ↓ P_G	Arterial pressure
c) ↓ efferent arteriolar resistance (R_E)→ ↓ P_G	↓ Angiotensin II (drugs that block angiotensin II formation)

P_{G} : Glomerular hydrostatic pressure

π_{B} : Colloid osmotic pressure of the proteins in Bowman's capsule

P_{B} : Hydrostatic pressure in Bowman's capsule

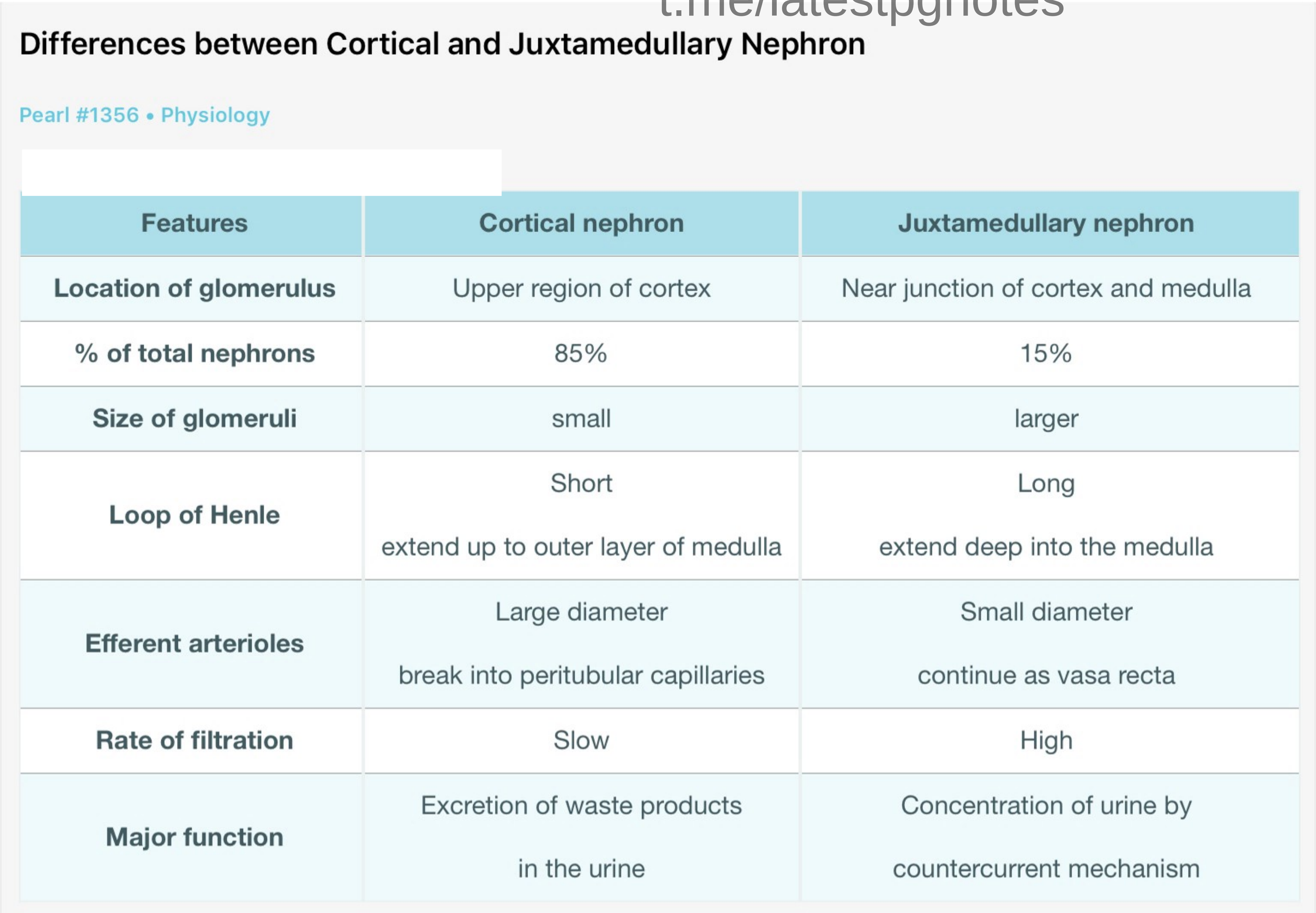
π_{G} : Colloid osmotic pressure of glomerular capillary plasma proteins



Agents causing Relaxation and Contraction of the Mesangial Cells

Pearl #1358 • Physiology

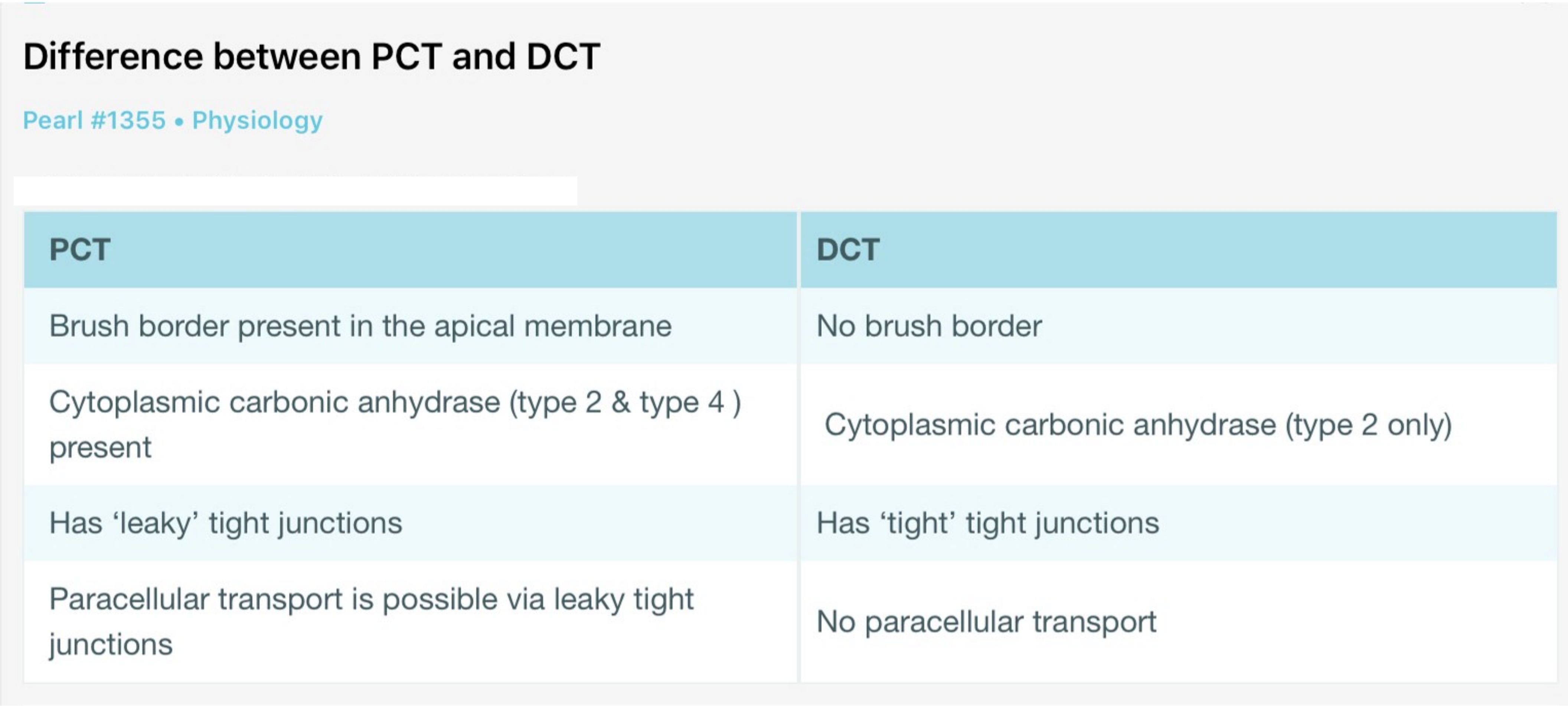
Relaxation	Contraction
• ANP • Dopamine • PGE2 • cAMP	• Endothelins • Angiotension II • Vasopressin • Platelet-derived growth factor • Thromboxane A2 • PGF2 • Leukotrienes C4 and D4 • Histamine



Differences between Cortical and Juxtamedullary Nephron

Pearl #1356 • Physiology

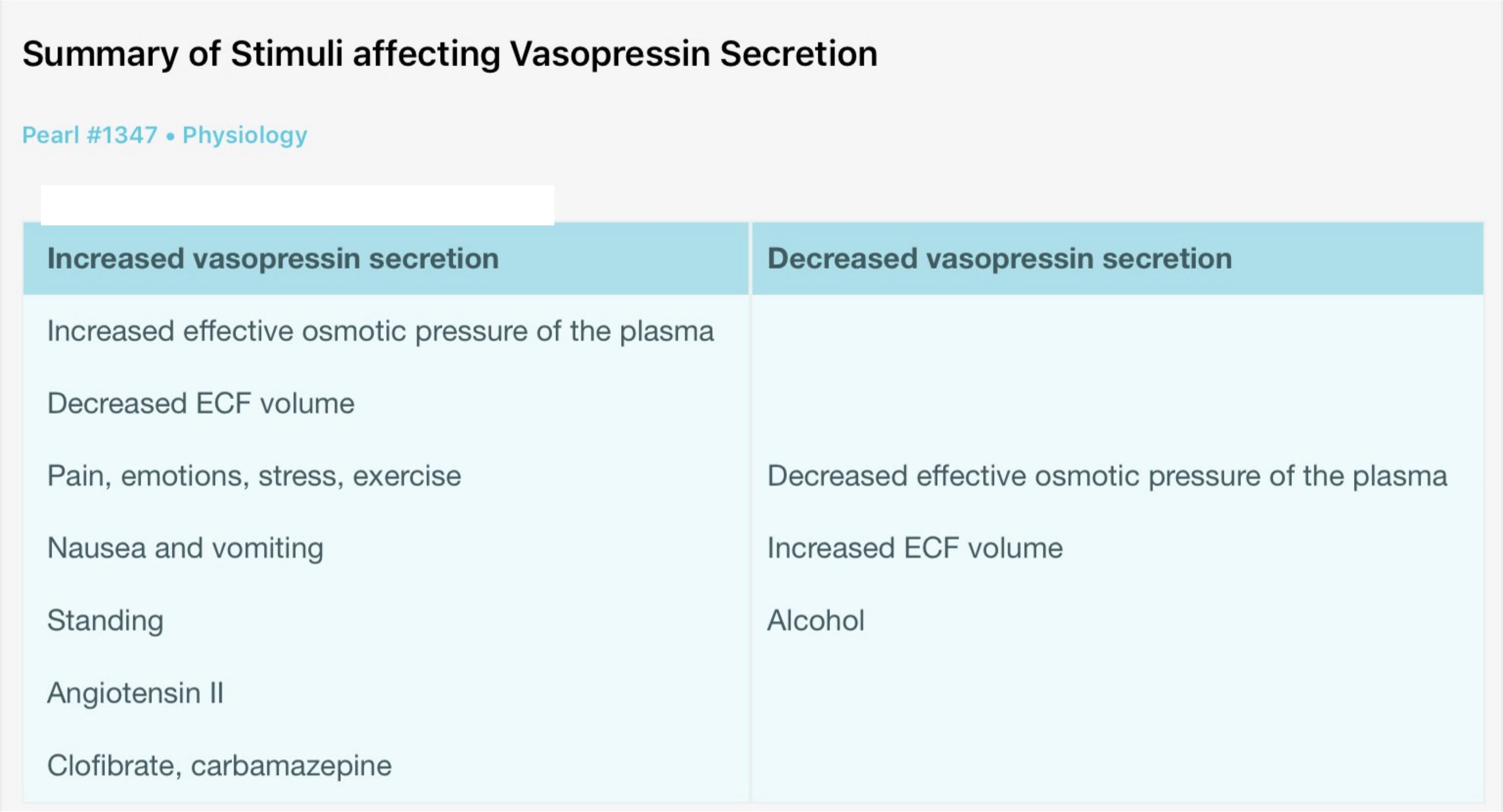
Features	Cortical nephron	Juxtamedullary nephron
Location of glomerulus	Upper region of cortex	Near junction of cortex and medulla
% of total nephrons	85%	15%
Size of glomeruli	small	larger
Loop of Henle	Short extend up to outer layer of medulla	Long extend deep into the medulla
Efferent arterioles	Large diameter break into peritubular capillaries	Small diameter continue as vasa recta
Rate of filtration	Slow	High
Major function	Excretion of waste products in the urine	Concentration of urine by countercurrent mechanism



Difference between PCT and DCT

Pearl #1355 • Physiology

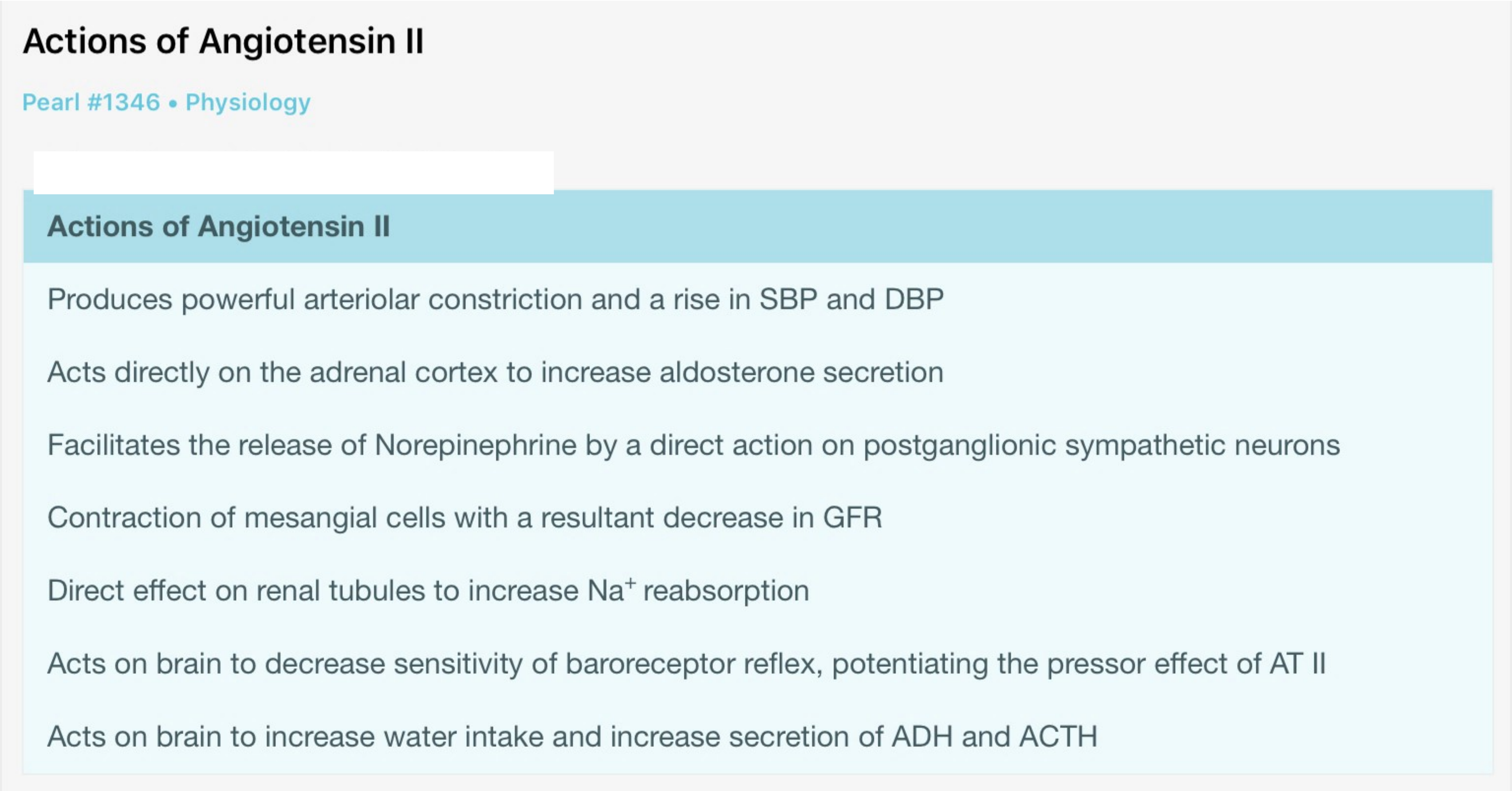
PCT	DCT
Brush border present in the apical membrane	No brush border
Cytoplasmic carbonic anhydrase (type 2 & type 4) present	Cytoplasmic carbonic anhydrase (type 2 only)
Has 'leaky' tight junctions	Has 'tight' tight junctions
Paracellular transport is possible via leaky tight junctions	No paracellular transport



Summary of Stimuli affecting Vasopressin Secretion

Pearl #1347 • Physiology

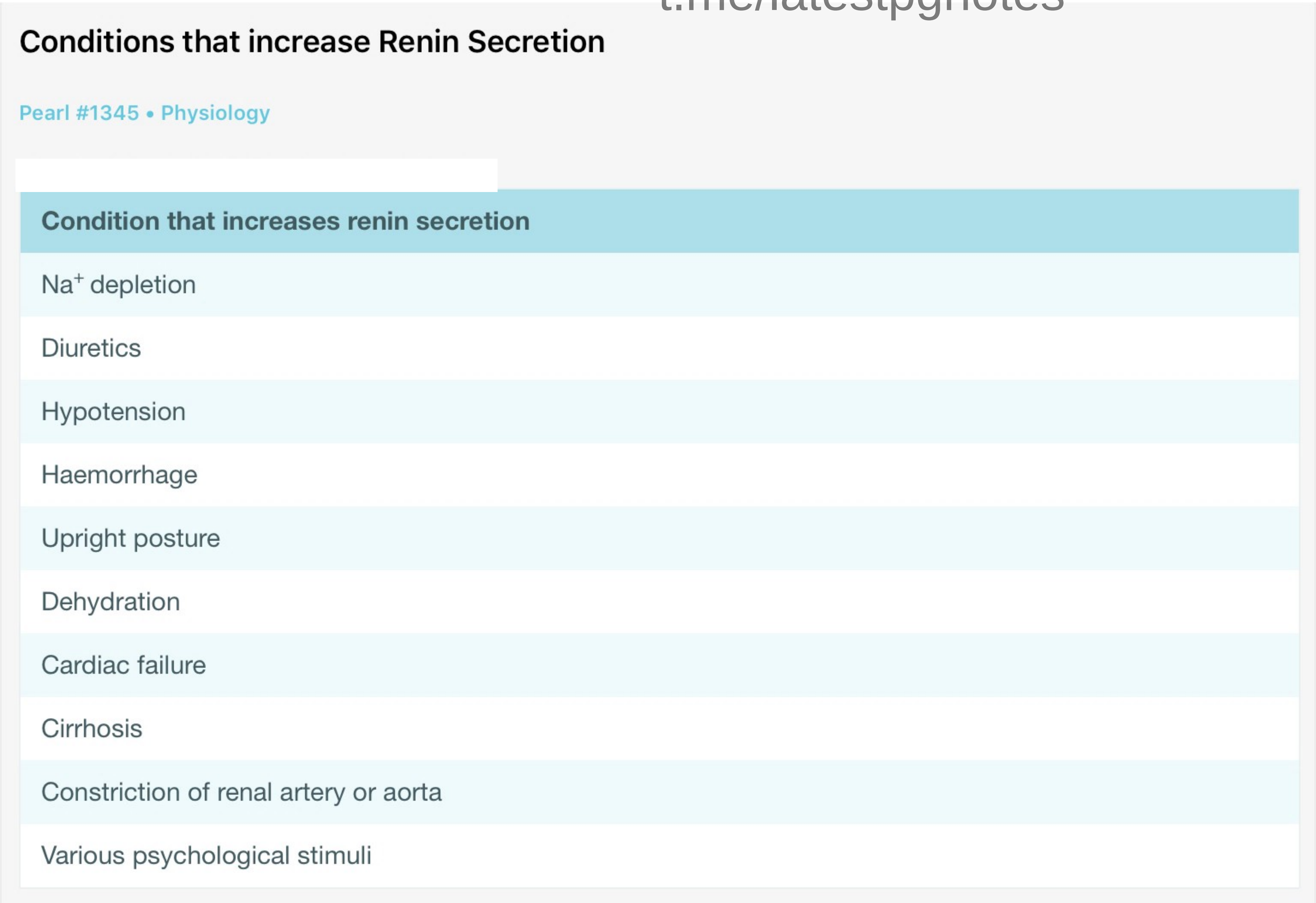
Increased vasopressin secretion	Decreased vasopressin secretion
Increased effective osmotic pressure of the plasma	
Decreased ECF volume	
Pain, emotions, stress, exercise	Decreased effective osmotic pressure of the plasma
Nausea and vomiting	Increased ECF volume
Standing	Alcohol
Angiotensin II	
Clofibrate, carbamazepine	



Actions of Angiotensin II

Pearl #1346 • Physiology

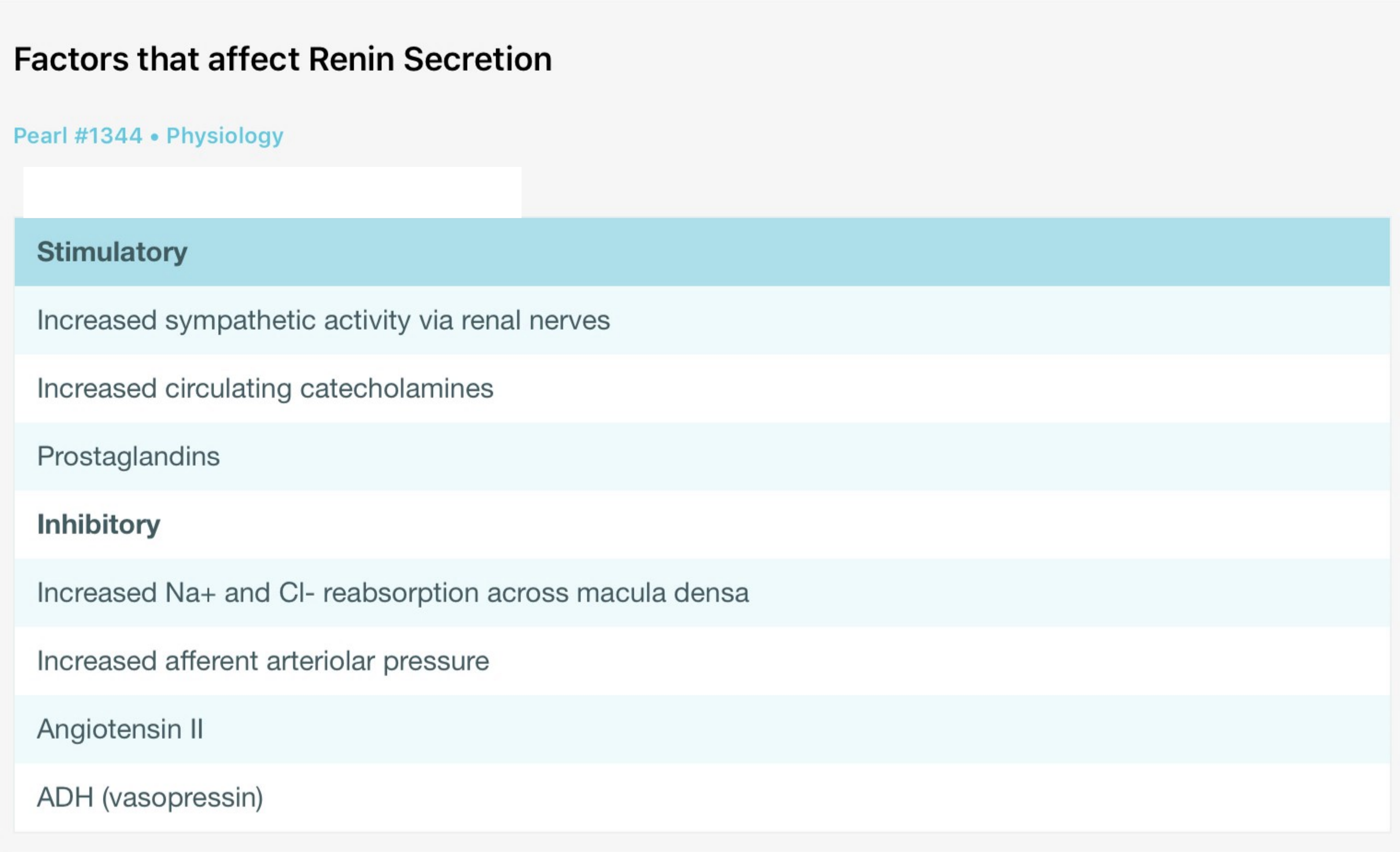
Actions of Angiotensin II
Produces powerful arteriolar constriction and a rise in SBP and DBP
Acts directly on the adrenal cortex to increase aldosterone secretion
Facilitates the release of Norepinephrine by a direct action on postganglionic sympathetic neurons
Contraction of mesangial cells with a resultant decrease in GFR
Direct effect on renal tubules to increase Na^+ reabsorption
Acts on brain to decrease sensitivity of baroreceptor reflex, potentiating the pressor effect of AT II
Acts on brain to increase water intake and increase secretion of ADH and ACTH



Conditions that increase Renin Secretion

Pearl #1345 • Physiology

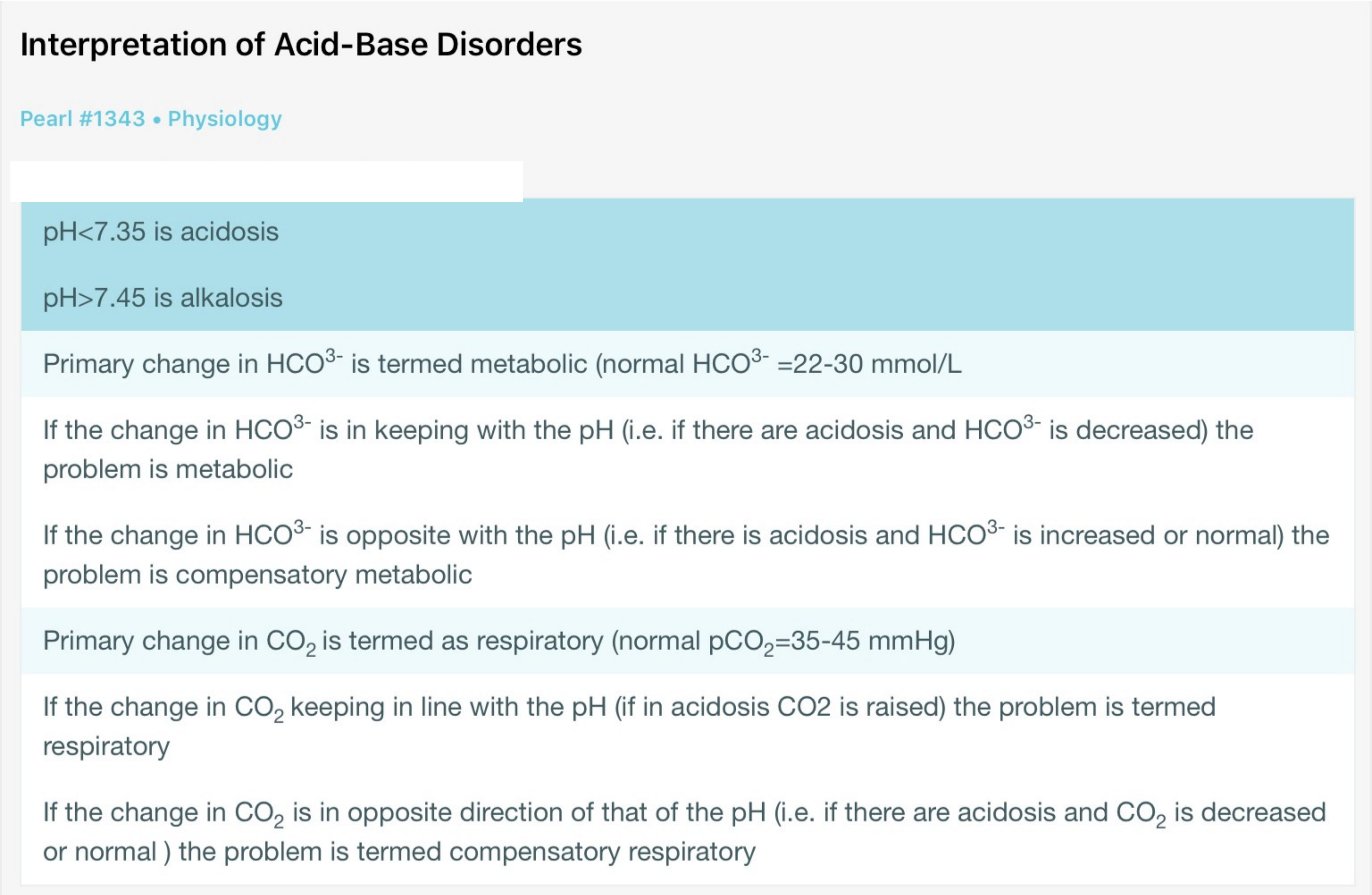
Condition that increases renin secretion
Na^+ depletion
Diuretics
Hypotension
Haemorrhage
Upright posture
Dehydration
Cardiac failure
Cirrhosis
Constriction of renal artery or aorta
Various psychological stimuli



Factors that affect Renin Secretion

Pearl #1344 • Physiology

Stimulatory
Increased sympathetic activity via renal nerves
Increased circulating catecholamines
Prostaglandins
Inhibitory
Increased Na+ and Cl- reabsorption across macula densa
Increased afferent arteriolar pressure
Angiotensin II
ADH (vasopressin)



Interpretation of Acid-Base Disorders

Pearl #1343 • Physiology

pH<7.35 is acidosis

pH>7.45 is alkalosis

Primary change in HCO^{3-} is termed metabolic (normal HCO^{3-} =22-30 mmol/L

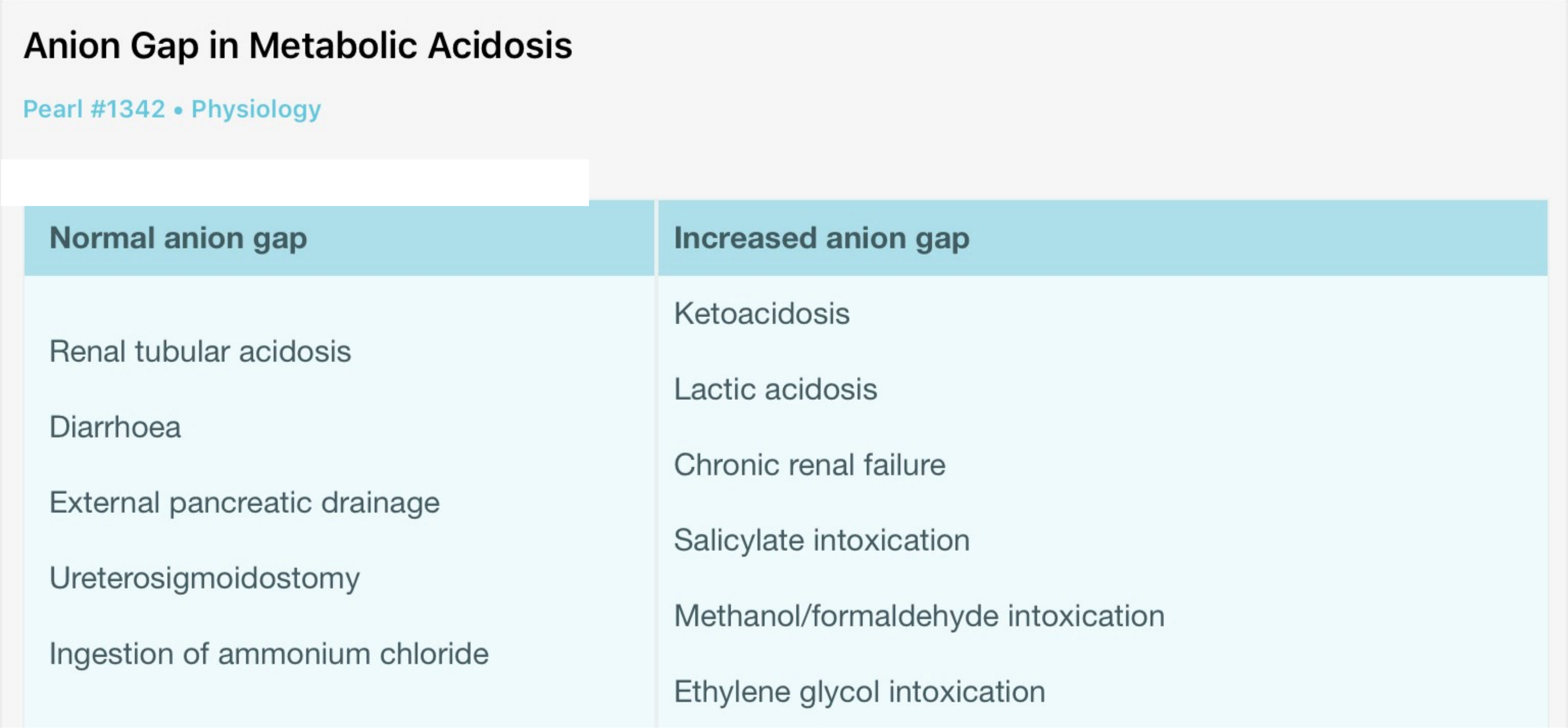
If the change in HCO^{3-} is in keeping with the pH (i.e. if there are acidosis and HCO^{3-} is decreased) the problem is metabolic

If the change in HCO^{3-} is opposite with the pH (i.e. if there is acidosis and HCO^{3-} is increased or normal) the problem is compensatory metabolic

Primary change in CO_2 is termed as respiratory (normal pCO_2=35-45 mmHg)

If the change in CO_2 keeping in line with the pH (if in acidosis CO2 is raised) the problem is termed respiratory

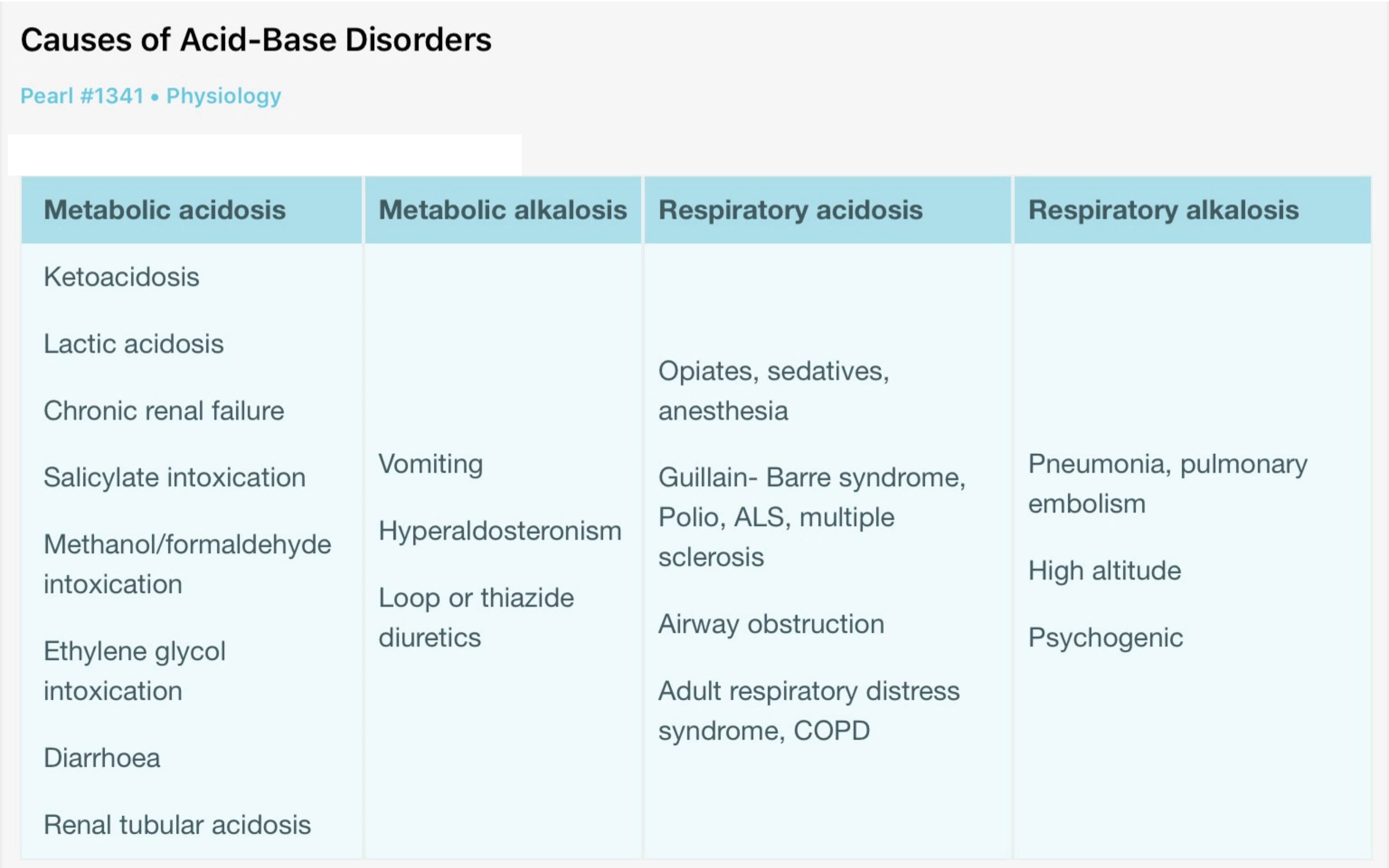
If the change in CO_2 is in opposite direction of that of the pH (i.e. if there are acidosis and CO_2 is decreased or normal) the problem is termed compensatory respiratory



Anion Gap in Metabolic Acidosis

Pearl #1342 • Physiology

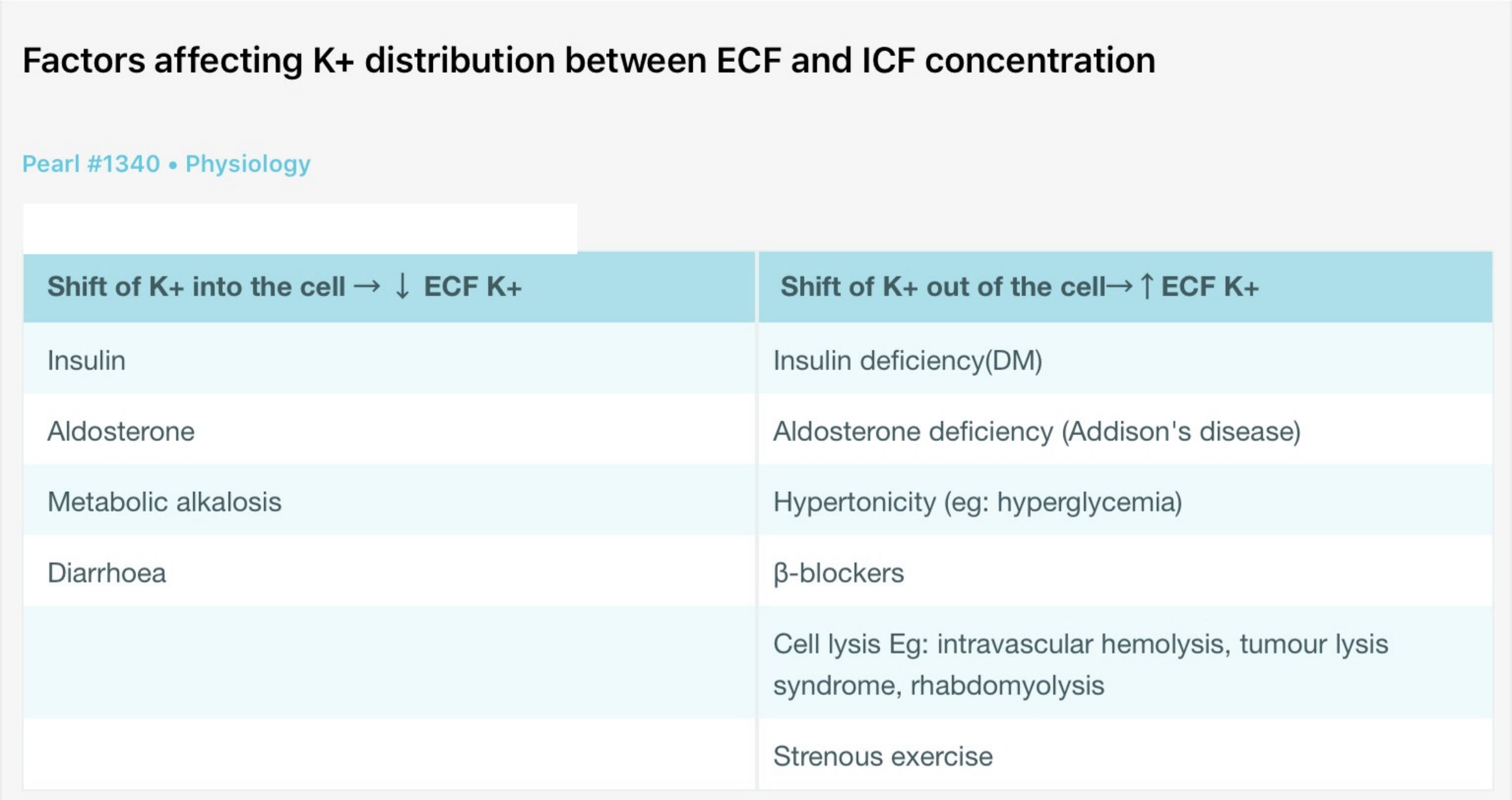
Normal anion gap	Increased anion gap
Renal tubular acidosis	Ketoacidosis
Diarrhoea	Lactic acidosis
External pancreatic drainage	Chronic renal failure
Ureterosigmoidostomy	Salicylate intoxication
Ingestion of ammonium chloride	Methanol/formaldehyde intoxication
	Ethylene glycol intoxication



Causes of Acid-Base Disorders

Pearl #1341 • Physiology

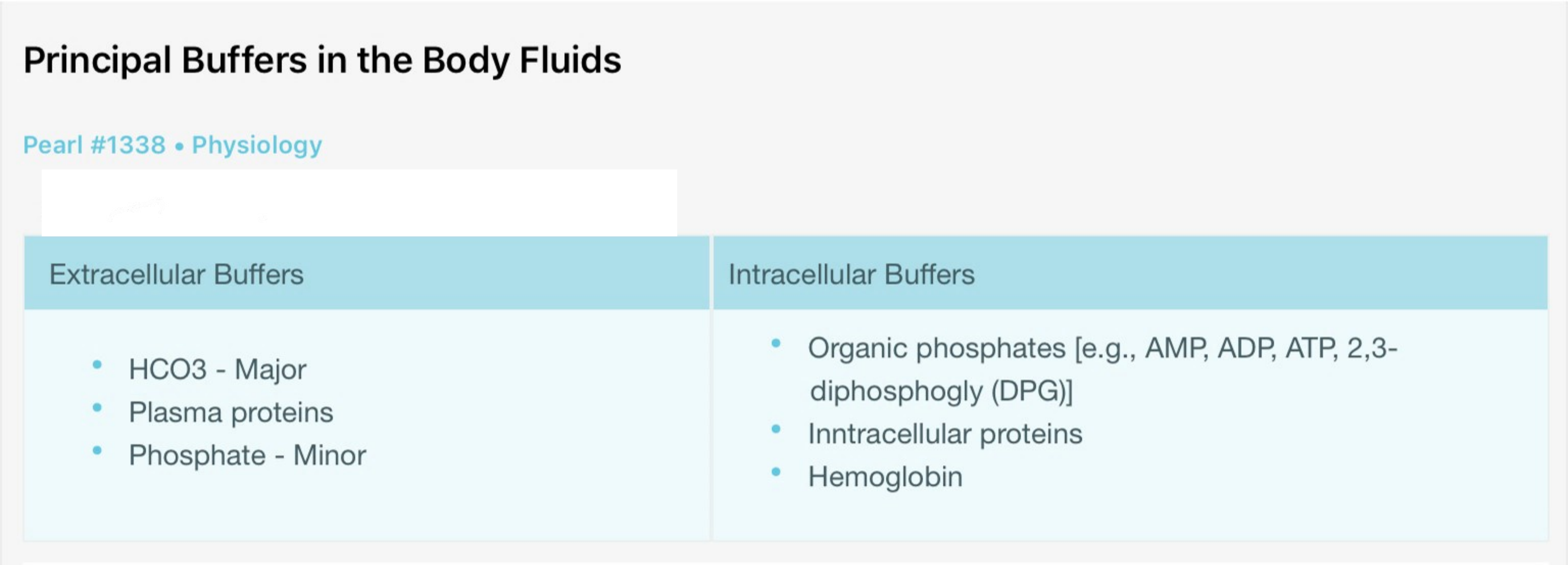
Metabolic acidosis	Metabolic alkalosis	Respiratory acidosis	Respiratory alkalosis
Ketoacidosis Lactic acidosis Chronic renal failure Salicylate intoxication Methanol/formaldehyde intoxication Ethylene glycol intoxication Diarrhoea Renal tubular acidosis	Vomiting Hyperaldosteronism Loop or thiazide diuretics	Opiates, sedatives, anesthesia Guillain- Barre syndrome, Polio, ALS, multiple sclerosis Airway obstruction Adult respiratory distress syndrome, COPD	Pneumonia, pulmonary embolism High altitude Psychogenic



Factors affecting K+ distribution between ECF and ICF concentration

Pearl #1340 • Physiology

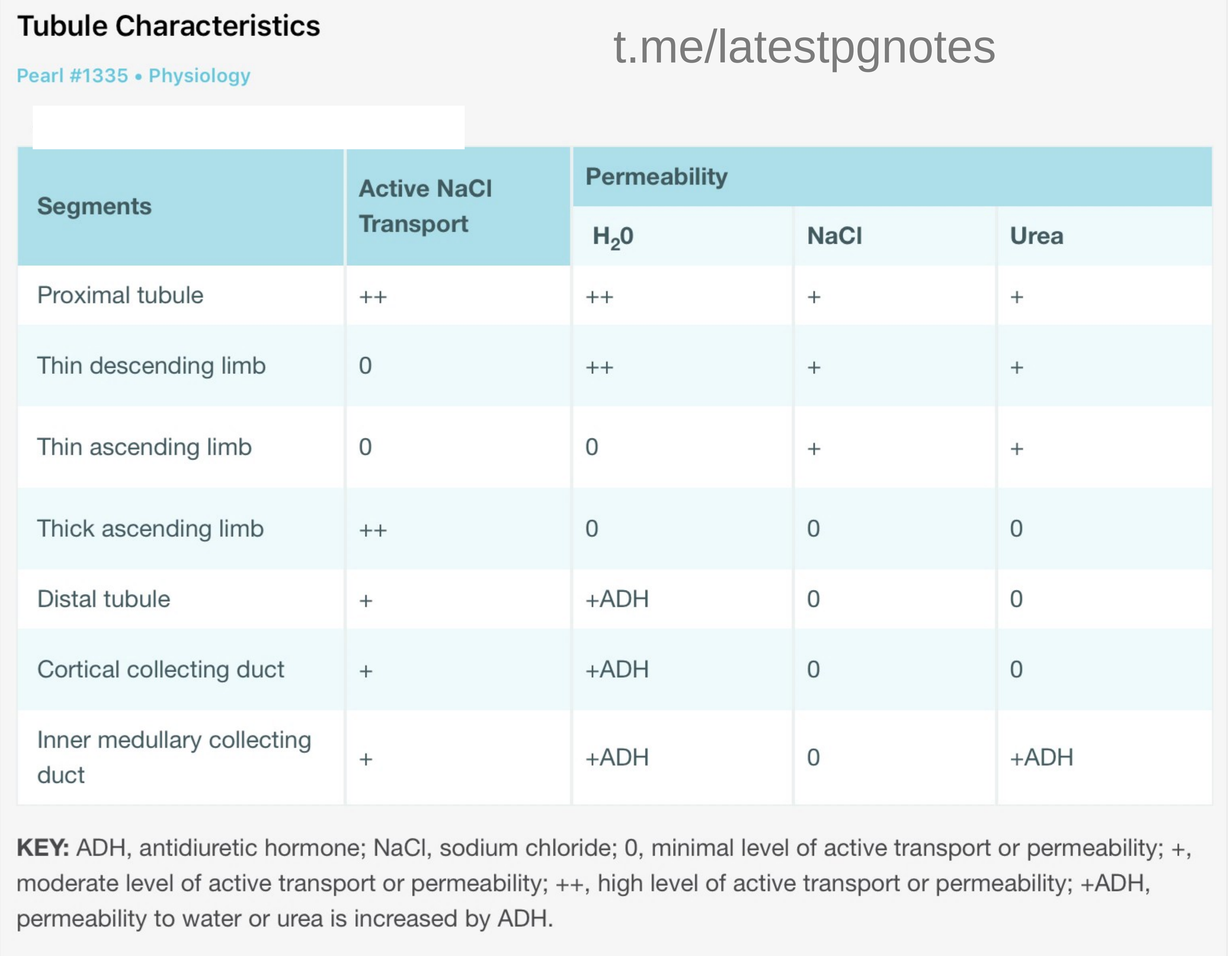
Shift of K+ into the cell → ↓ ECF K+	Shift of K+ out of the cell→ ↑ ECF K+
Insulin	Insulin deficiency(DM)
Aldosterone	Aldosterone deficiency (Addison's disease)
Metabolic alkalosis	Hypertonicity (eg: hyperglycemia)
Diarrhoea	β-blockers
	Cell lysis Eg: intravascular hemolysis, tumour lysis syndrome, rhabdomyolysis
	Strenous exercise



Principal Buffers in the Body Fluids

Pearl #1338 • Physiology

Extracellular Buffers	Intracellular Buffers
• HCO3 - Major • Plasma proteins • Phosphate - Minor	• Organic phosphates [e.g., AMP, ADP, ATP, 2,3-diphosphogly (DPG)] • Inntracellular proteins • Hemoglobin

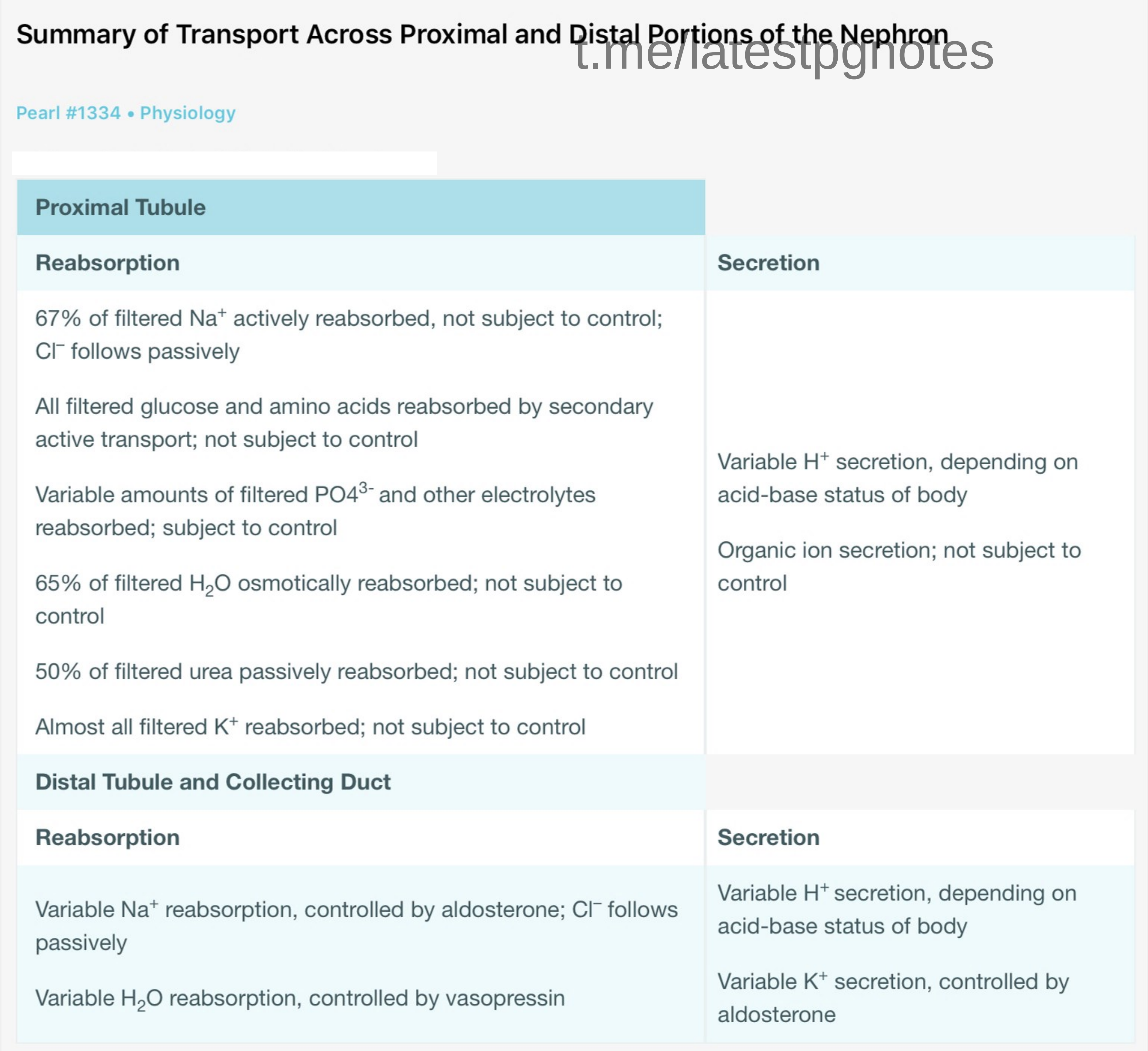


Tubule Characteristics

Pearl #1335 • Physiology

Segments	Active NaCl Transport	Permeability		
		H_20	NaCl	Urea
Proximal tubule	++	++	+	+
Thin descending limb	0	++	+	+
Thin ascending limb	0	0	+	+
Thick ascending limb	++	0	0	0
Distal tubule	+	+ADH	0	0
Cortical collecting duct	+	+ADH	0	0
Inner medullary collecting duct	+	+ADH	0	+ADH

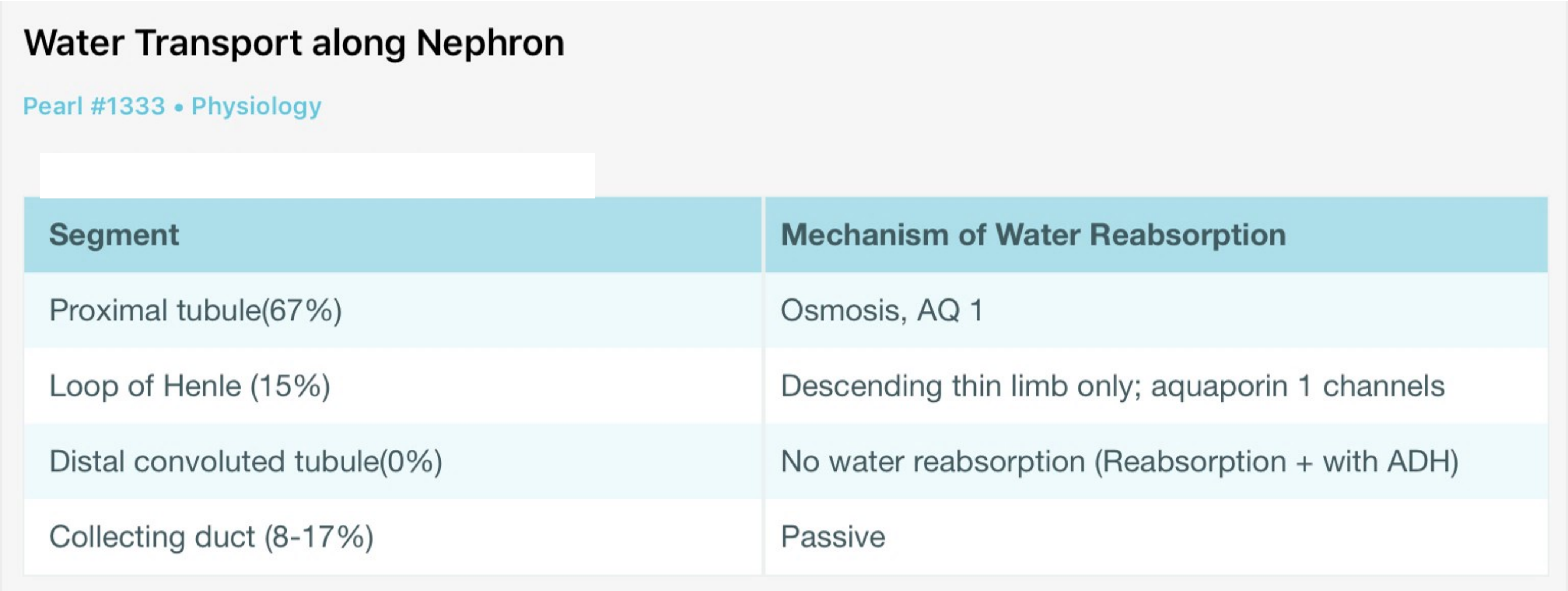
KEY: ADH, antidiuretic hormone; NaCl, sodium chloride; 0, minimal level of active transport or permeability; +, moderate level of active transport or permeability; ++, high level of active transport or permeability; +ADH, permeability to water or urea is increased by ADH.



Summary of Transport Across Proximal and Distal Portions of the Nephron

Pearl #1334 • Physiology

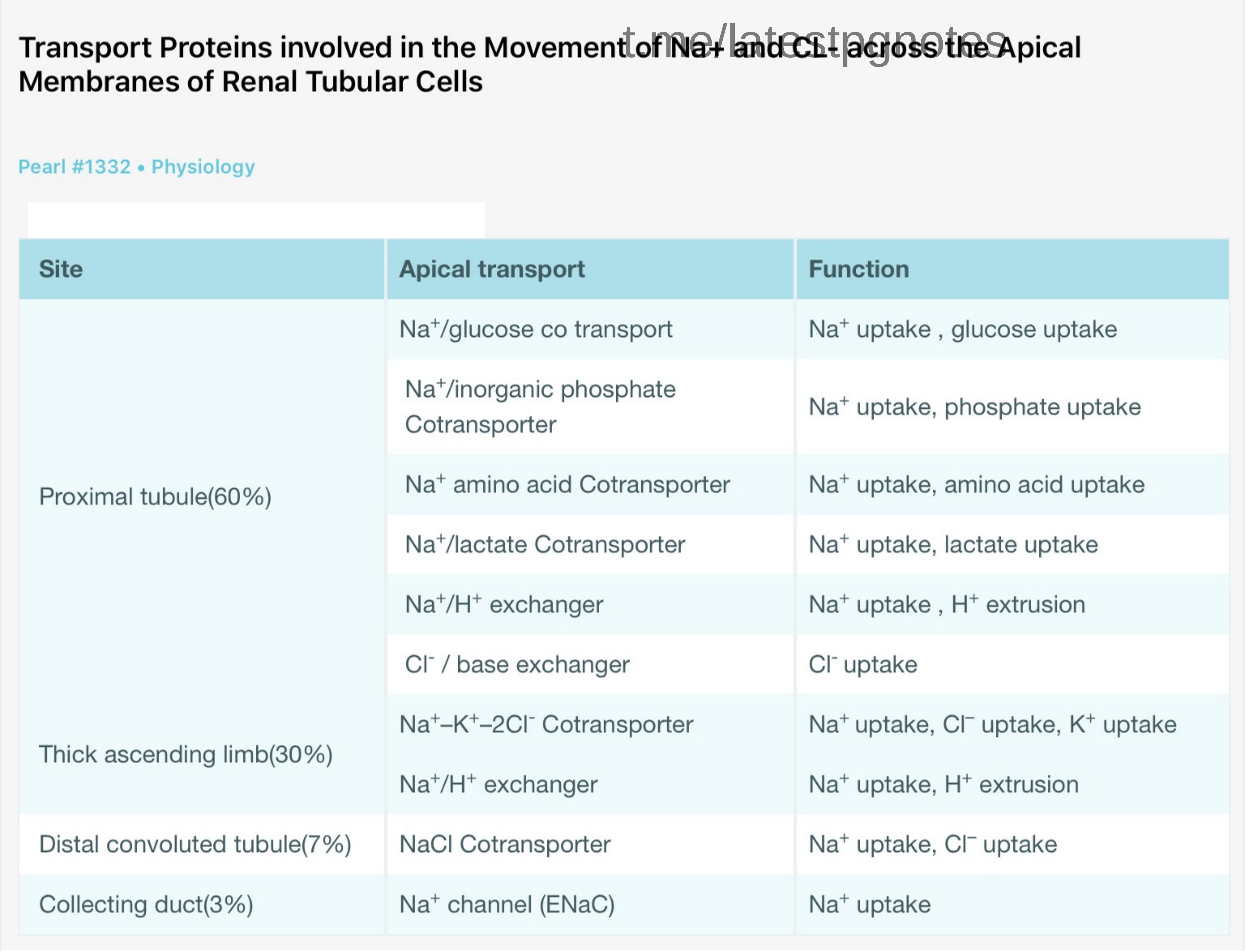
Proximal Tubule	
Reabsorption	**Secretion**
67% of filtered Na^+ actively reabsorbed, not subject to control; Cl^- follows passively All filtered glucose and amino acids reabsorbed by secondary active transport; not subject to control Variable amounts of filtered $PO4^{3-}$ and other electrolytes reabsorbed; subject to control 65% of filtered H_2O osmotically reabsorbed; not subject to control 50% of filtered urea passively reabsorbed; not subject to control Almost all filtered K^+ reabsorbed; not subject to control	Variable H^+ secretion, depending on acid-base status of body Organic ion secretion; not subject to control
Distal Tubule and Collecting Duct	
Reabsorption	**Secretion**
Variable Na^+ reabsorption, controlled by aldosterone; Cl^- follows passively Variable H_2O reabsorption, controlled by vasopressin	Variable H^+ secretion, depending on acid-base status of body Variable K^+ secretion, controlled by aldosterone



Water Transport along Nephron

Pearl #1333 • Physiology

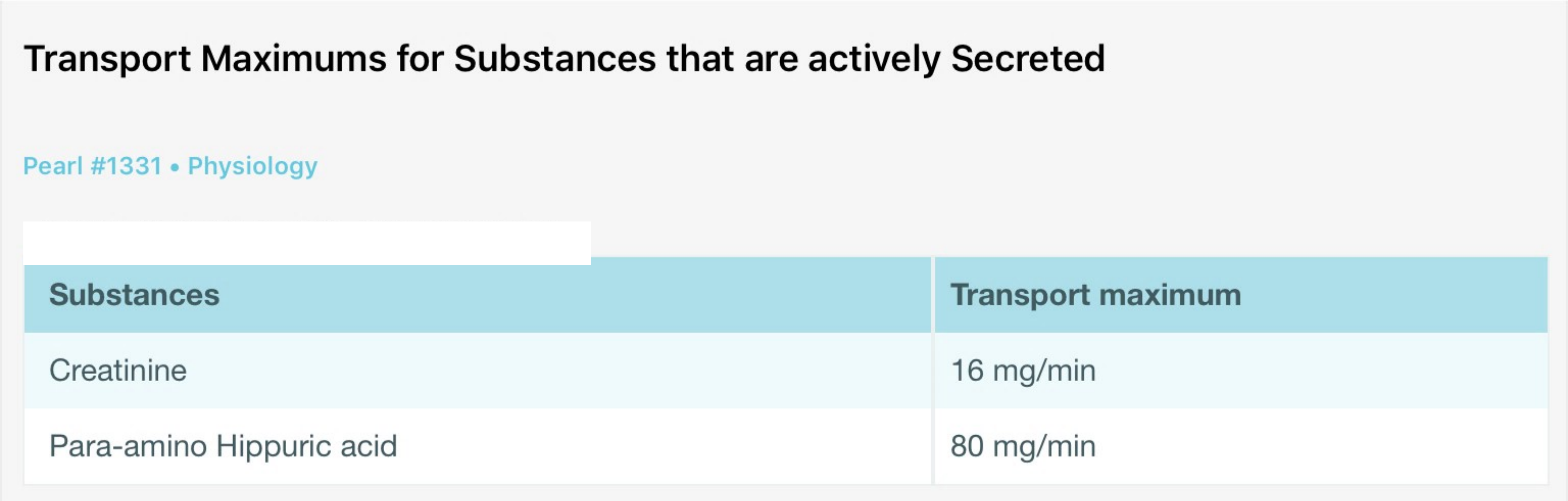
Segment	Mechanism of Water Reabsorption
Proximal tubule(67%)	Osmosis, AQ 1
Loop of Henle (15%)	Descending thin limb only; aquaporin 1 channels
Distal convoluted tubule(0%)	No water reabsorption (Reabsorption + with ADH)
Collecting duct (8-17%)	Passive



Transport Proteins involved in the Movement of Na+ and CL- across the Apical Membranes of Renal Tubular Cells

Pearl #1332 • Physiology

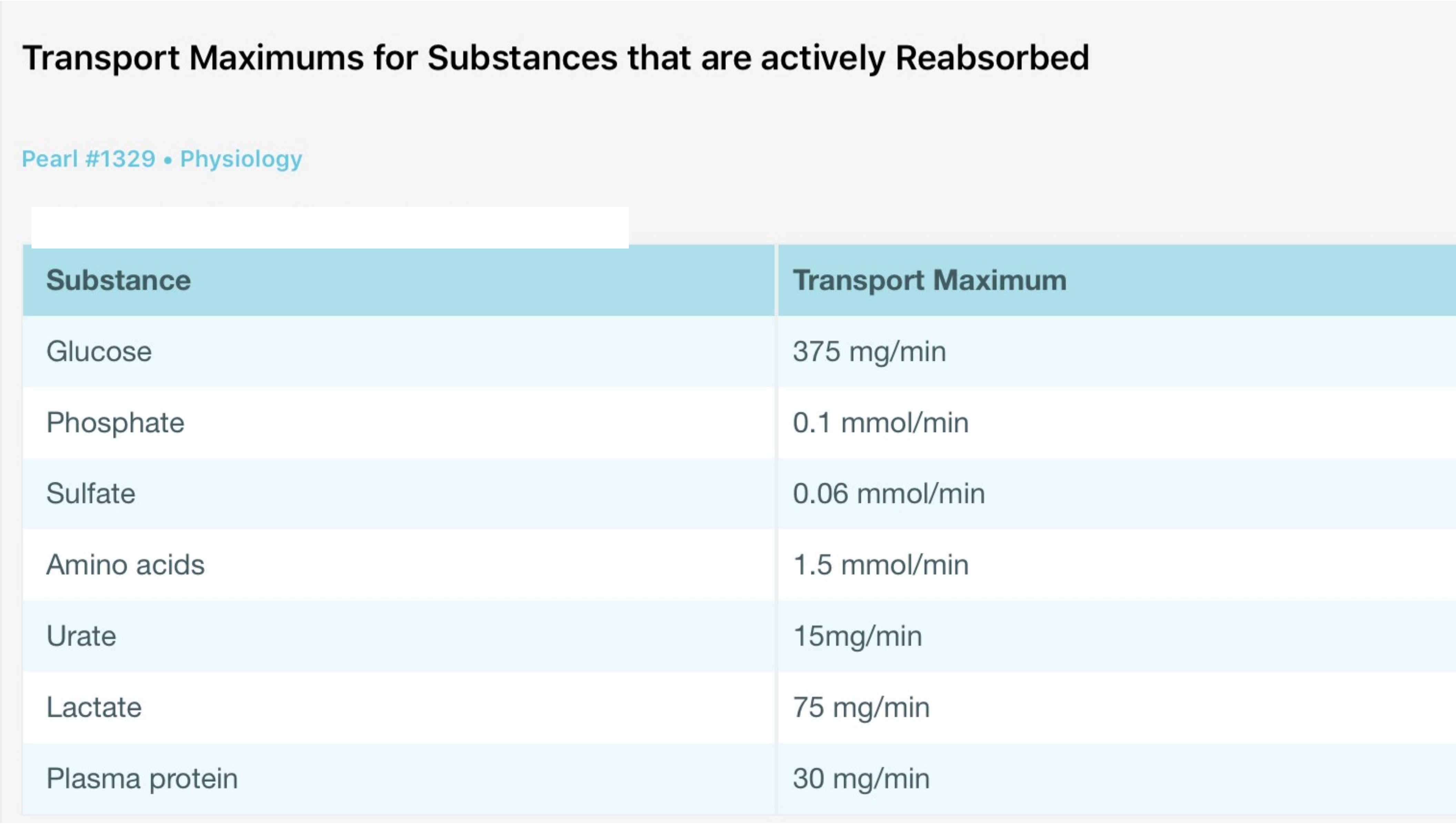
Site	Apical transport	Function
Proximal tubule(60%)	Na^+/glucose co transport	Na^+ uptake , glucose uptake
	Na^+/inorganic phosphate Cotransporter	Na^+ uptake, phosphate uptake
	Na^+ amino acid Cotransporter	Na^+ uptake, amino acid uptake
	Na^+/lactate Cotransporter	Na^+ uptake, lactate uptake
	Na^+/H^+ exchanger	Na^+ uptake , H^+ extrusion
	Cl^- / base exchanger	Cl^- uptake
Thick ascending limb(30%)	Na^+–K^+–$2Cl^-$ Cotransporter	Na^+ uptake, Cl^- uptake, K^+ uptake
	Na^+/H^+ exchanger	Na^+ uptake, H^+ extrusion
Distal convoluted tubule(7%)	NaCl Cotransporter	Na^+ uptake, Cl^- uptake
Collecting duct(3%)	Na^+ channel (ENaC)	Na^+ uptake



Transport Maximums for Substances that are actively Secreted

Pearl #1331 • Physiology

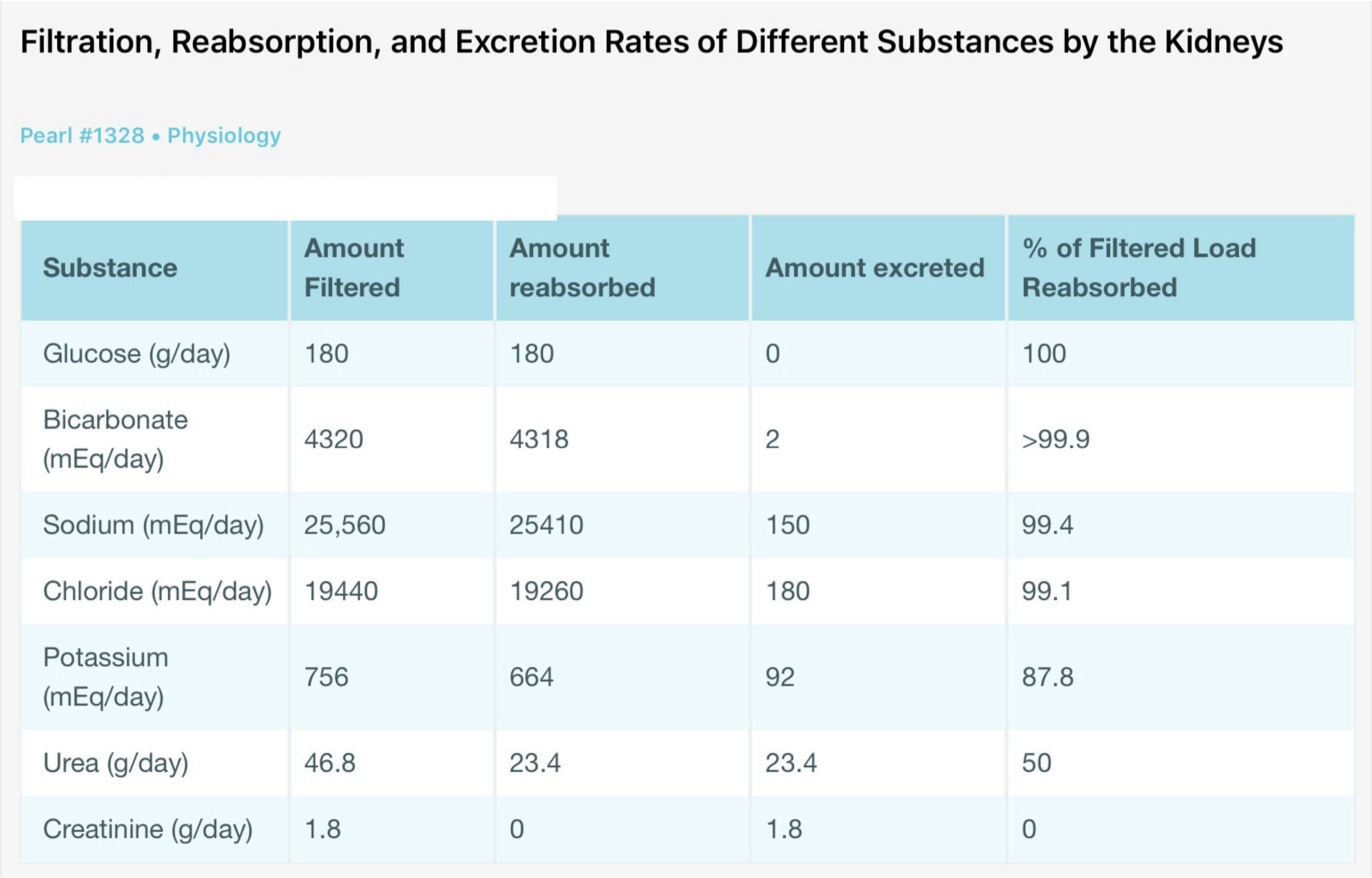
Substances	Transport maximum
Creatinine	16 mg/min
Para-amino Hippuric acid	80 mg/min



Transport Maximums for Substances that are actively Reabsorbed

Pearl #1329 • Physiology

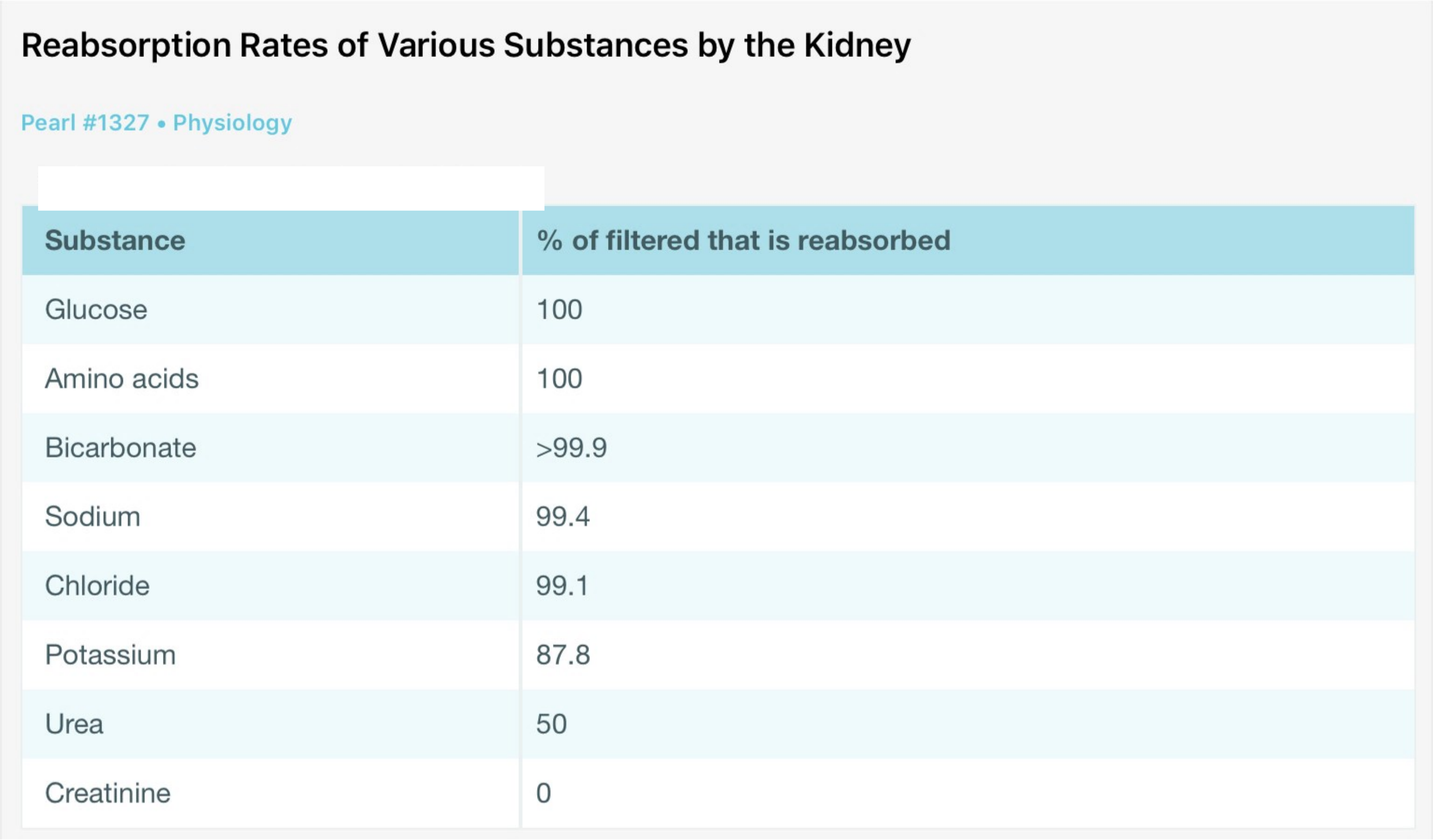
Substance	Transport Maximum
Glucose	375 mg/min
Phosphate	0.1 mmol/min
Sulfate	0.06 mmol/min
Amino acids	1.5 mmol/min
Urate	15mg/min
Lactate	75 mg/min
Plasma protein	30 mg/min



Filtration, Reabsorption, and Excretion Rates of Different Substances by the Kidneys

Pearl #1328 • Physiology

Substance	Amount Filtered	Amount reabsorbed	Amount excreted	% of Filtered Load Reabsorbed
Glucose (g/day)	180	180	0	100
Bicarbonate (mEq/day)	4320	4318	2	>99.9
Sodium (mEq/day)	25,560	25410	150	99.4
Chloride (mEq/day)	19440	19260	180	99.1
Potassium (mEq/day)	756	664	92	87.8
Urea (g/day)	46.8	23.4	23.4	50
Creatinine (g/day)	1.8	0	1.8	0



Reabsorption Rates of Various Substances by the Kidney

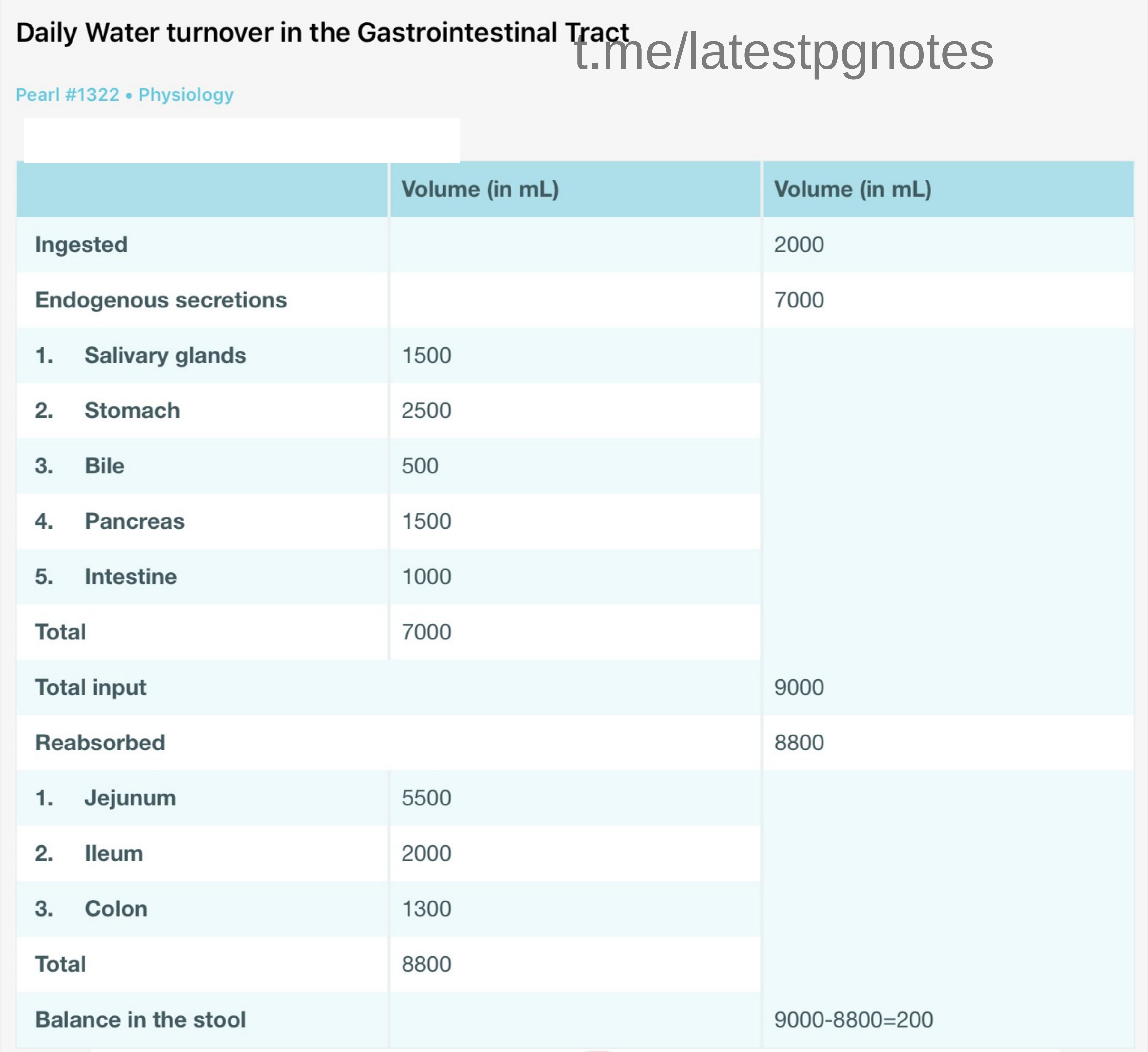
Pearl #1327 • Physiology

Substance	% of filtered that is reabsorbed
Glucose	100
Amino acids	100
Bicarbonate	>99.9
Sodium	99.4
Chloride	99.1
Potassium	87.8
Urea	50
Creatinine	0

Neurotransmitters and Hormones that influence Feeding and Satiety Centers in the Hypothalamus

Pearl #1323 • Physiology

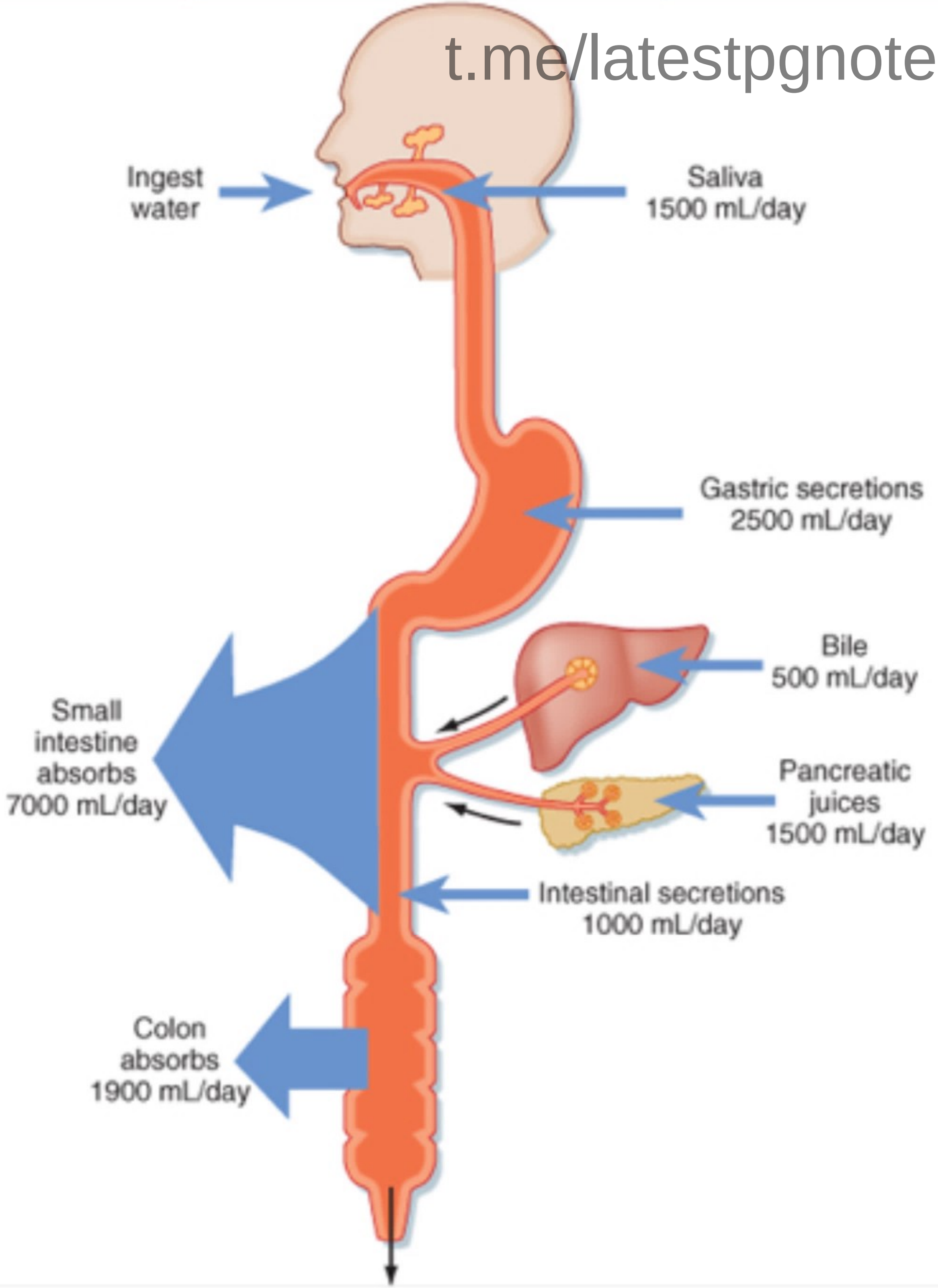
Increased Appetite (Orexigenic)	**Decreased Appetite (Anorexigenic)**
Neuropeptide Y	Melanocyte-stimulating hormone (MSH)
Agouti-related protein (AGRP)	Leptin
Melanin-concentrating hormone (MCH)	Serotonin
Orexins A and B	Norepinephrine
Endorphins	Corticotropin-releasing hormone (CRH)
Galanin	Insulin
Amino acids (glutamate and γ aminobutyric acid)	Cholecystokinin (CCK)
Cortisol	Glucagon-like peptide
Ghrelin	Cocaine-and amphetamine-regulated transcript (CART)
Growth hormone-releasing hormone (GHRH)	Bombesin
Endocannabinoids	Peptide YY



Daily Water turnover in the Gastrointestinal Tract

Pearl #1322 • Physiology

	Volume (in mL)	Volume (in mL)
Ingested		2000
Endogenous secretions		7000
1. Salivary glands	1500	
2. Stomach	2500	
3. Bile	500	
4. Pancreas	1500	
5. Intestine	1000	
Total	7000	
Total input		9000
Reabsorbed		8800
1. Jejunum	5500	
2. Ileum	2000	
3. Colon	1300	
Total	8800	
Balance in the stool		9000-8800=200


Ingest water
Saliva 1500 mL/day
Gastric secretions 2500 mL/day
Bile 500 mL/day
Small intestine absorbs 7000 mL/day
Pancreatic juices 1500 mL/day
Intestinal secretions 1000 mL/day
Colon absorbs 1900 mL/day

Proteases

Pearl #1321 • Physiology

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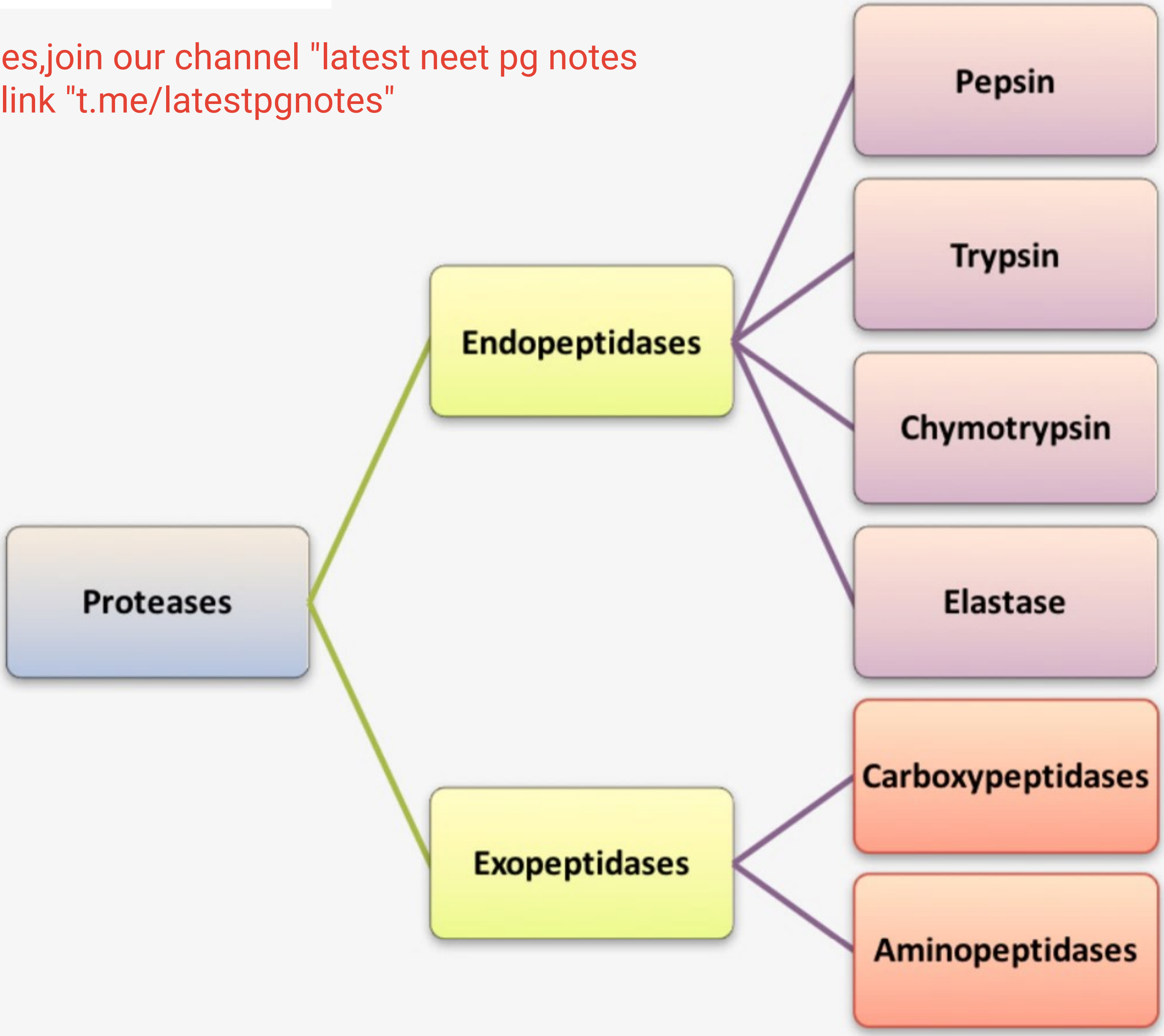

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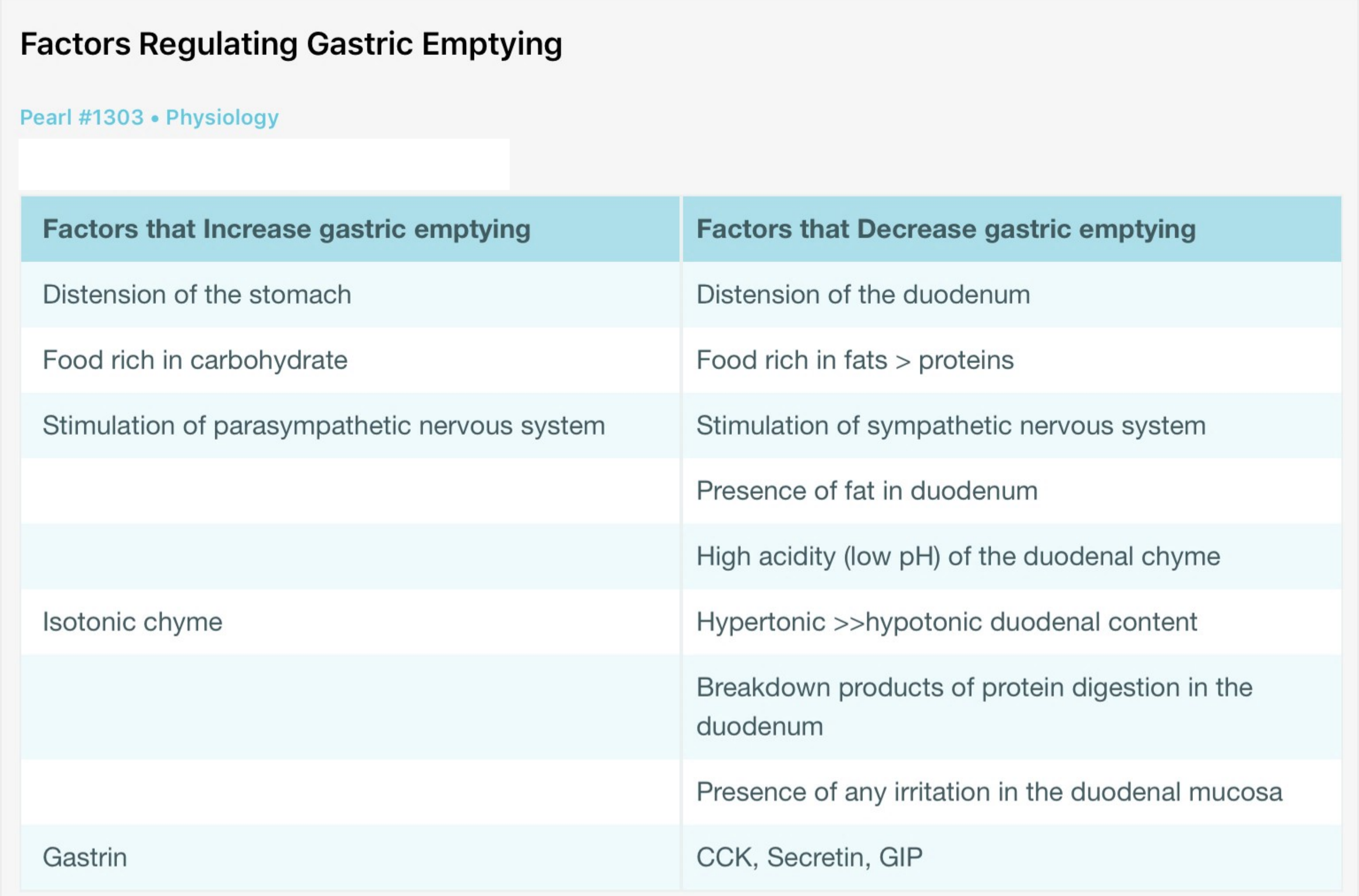


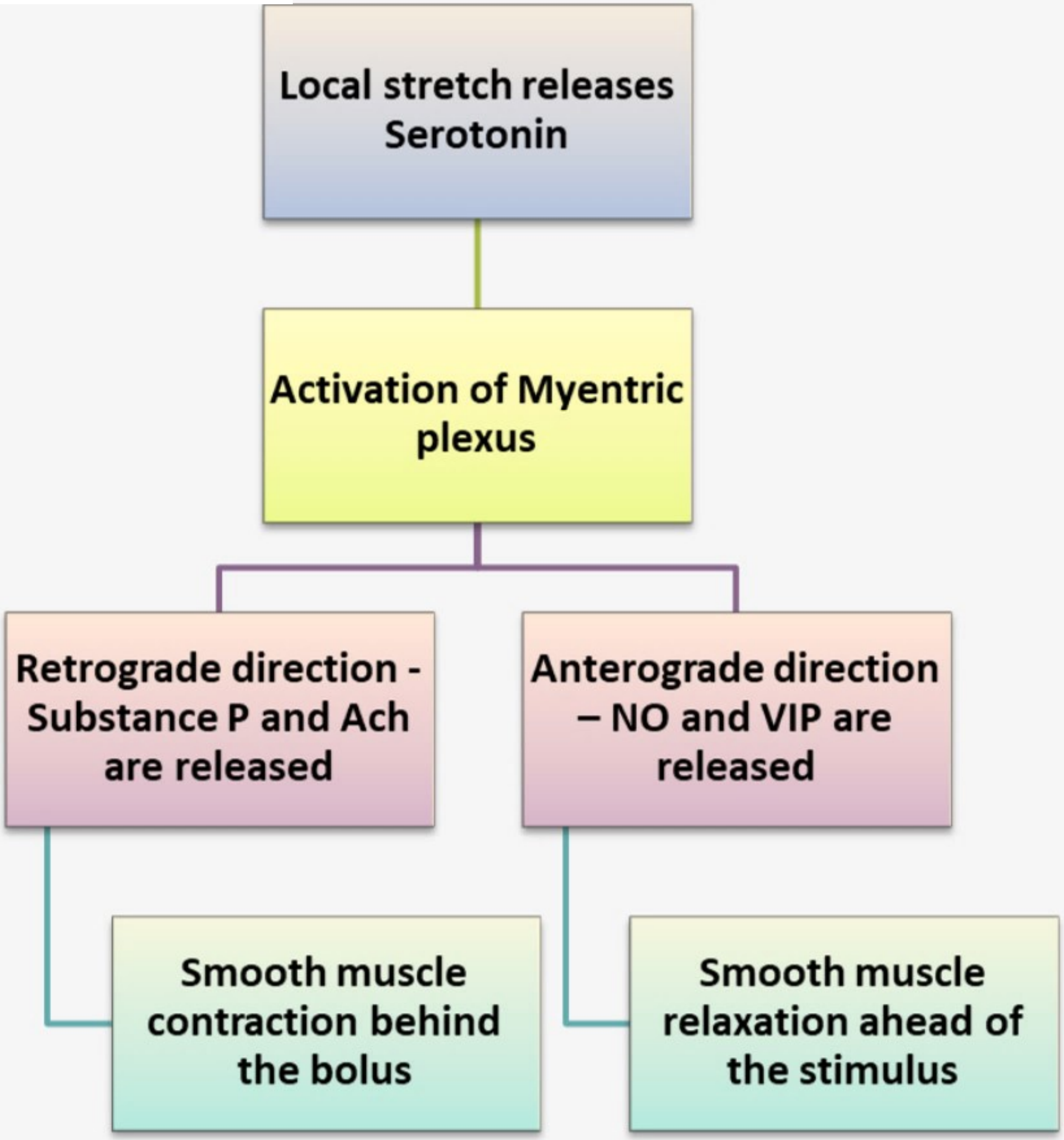
Factors Regulating Gastric Emptying

Pearl #1303 • Physiology

Factors that Increase gastric emptying	Factors that Decrease gastric emptying
Distension of the stomach	Distension of the duodenum
Food rich in carbohydrate	Food rich in fats > proteins
Stimulation of parasympathetic nervous system	Stimulation of sympathetic nervous system
	Presence of fat in duodenum
	High acidity (low pH) of the duodenal chyme
Isotonic chyme	Hypertonic >>hypotonic duodenal content
	Breakdown products of protein digestion in the duodenum
	Presence of any irritation in the duodenal mucosa
Gastrin	CCK, Secretin, GIP

Mechanism of Peristalisis

Pearl #1301 • Physiology



Local stretch releases Serotonin

Activation of Myentric plexus

Retrograde direction - Substance P and Ach are released

Anterograde direction – NO and VIP are released

Smooth muscle contraction behind the bolus

Smooth muscle relaxation ahead of the stimulus

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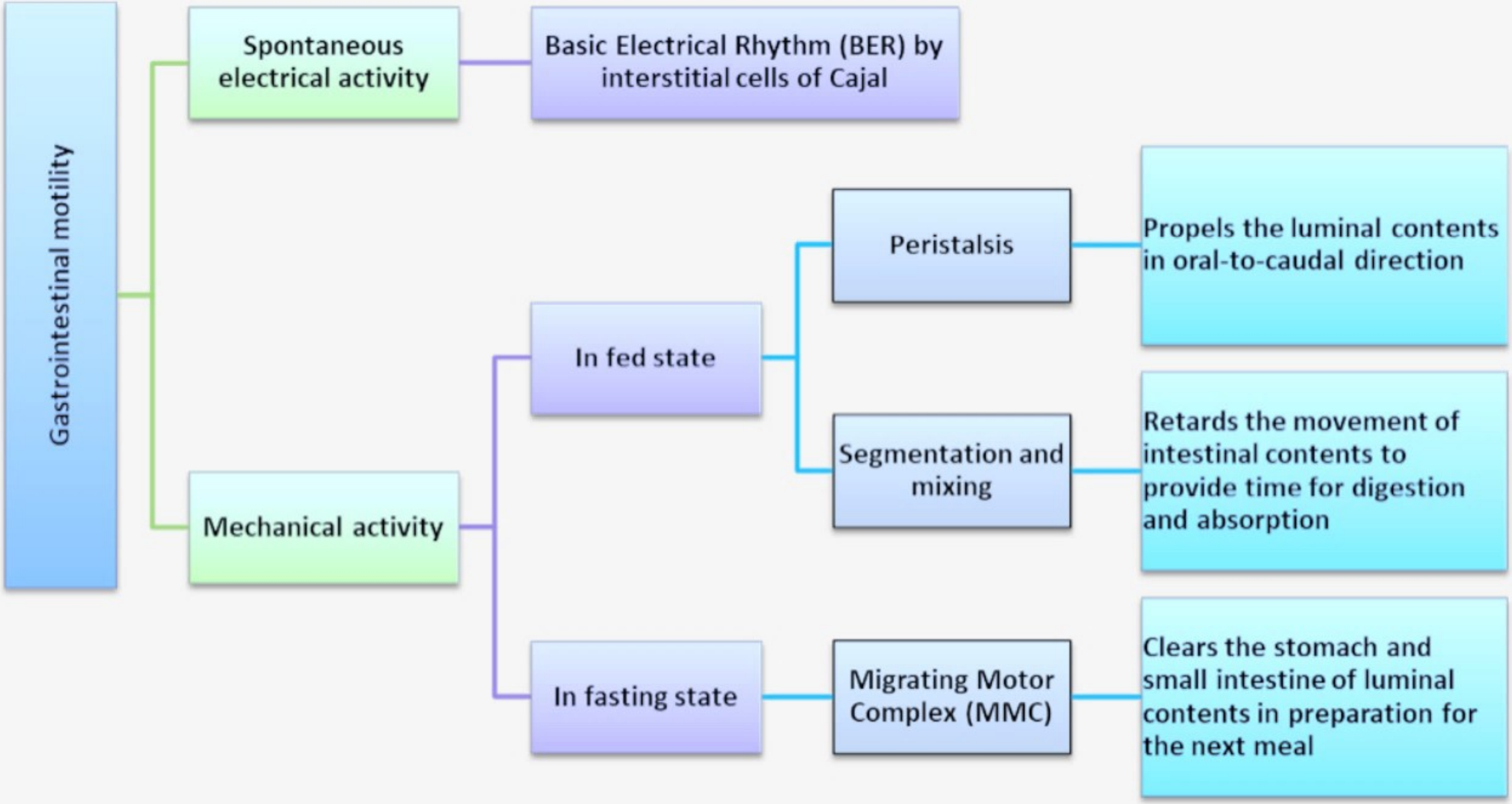
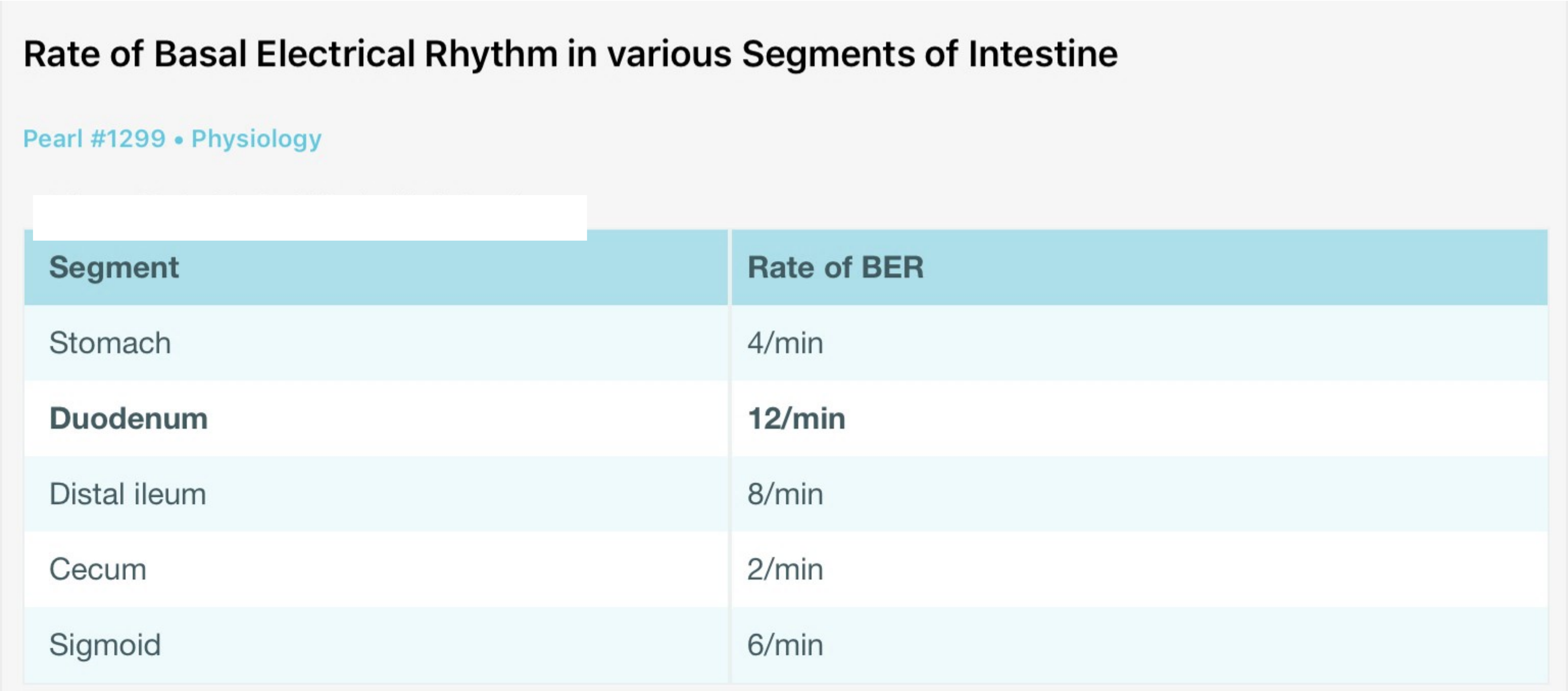
Types of Gastrointestinal Motility

Pearl #1300 • Physiology



- Gastrointestinal motility
  - Spontaneous electrical activity
    - Basic Electrical Rhythm (BER) by interstitial cells of Cajal
  - Mechanical activity
    - In fed state
      - Peristalsis
        - Propels the luminal contents in oral-to-caudal direction
      - Segmentation and mixing
        - Retards the movement of intestinal contents to provide time for digestion and absorption
    - In fasting state
      - Migrating Motor Complex (MMC)
        - Clears the stomach and small intestine of luminal contents in preparation for the next meal



Rate of Basal Electrical Rhythm in various Segments of Intestine

Pearl #1299 • Physiology

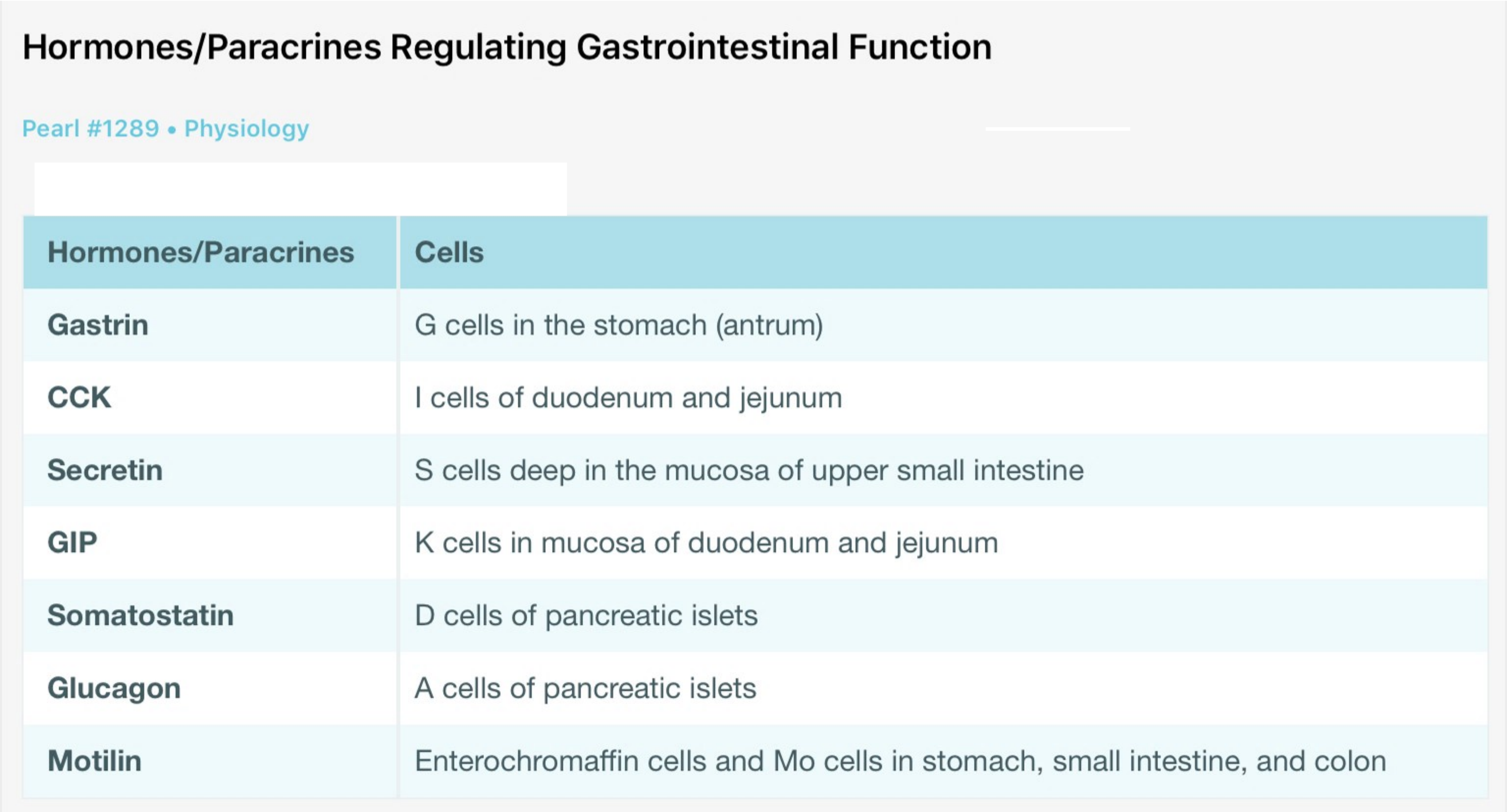
[redacted]

Segment	Rate of BER
Stomach	4/min
Duodenum	**12/min**
Distal ileum	8/min
Cecum	2/min
Sigmoid	6/min

Source and Actions of Gastrointestinal Hormones

Pearl #1290 • Physiology

Action	Gastrin	CCK	Secretin	GIP	Motilin
Source	G cells in the stomach (antrum)	I cells of duodenum and jejunum	S cells deep in the mucosa of upper small intestine	K cells in mucosa of duodenum and jejunum	Enterochromaffin cells and Mo cells in stomach, small intestine and colon
Acid secretion	**S**	**I**	**I**	**I**	
Gastric emptying	**S**	**I**	**I**	**I**	
Pancreatic HCO^{3-}	**S**	**S**	**S**	**0**	
Pancreatic enzymes	**S**	**S**	**S**	**0**	
Gall bladder contraction	**S**	**S**	**S**		
Gastric motility	**S**	**I**	**I**	**I**	**S**
Intestinal motility	**S**	**S**	**I**		**S**
Insulin release	**S**	**S**	**S**	**S**	
Mucosal growth	**S**	**S**	**I**		
Pancreatic growth	**S**	**S**	**S**		



Hormones/Paracrines Regulating Gastrointestinal Function

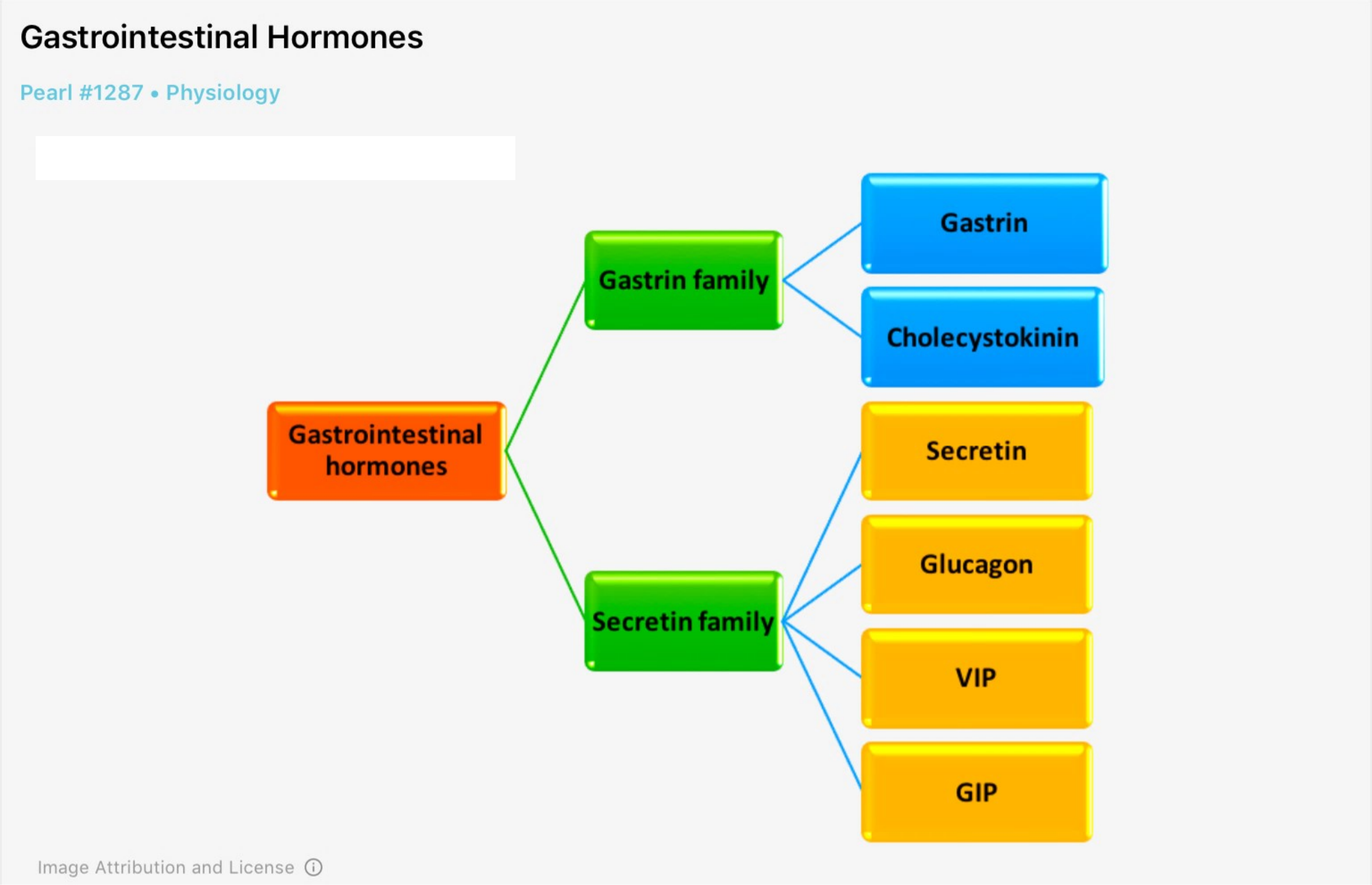
Pearl #1289 • Physiology

Hormones/Paracrines	Cells
Gastrin	G cells in the stomach (antrum)
CCK	I cells of duodenum and jejunum
Secretin	S cells deep in the mucosa of upper small intestine
GIP	K cells in mucosa of duodenum and jejunum
Somatostatin	D cells of pancreatic islets
Glucagon	A cells of pancreatic islets
Motilin	Enterochromaffin cells and Mo cells in stomach, small intestine, and colon

Stimuli that Affect Gastrin Secretion

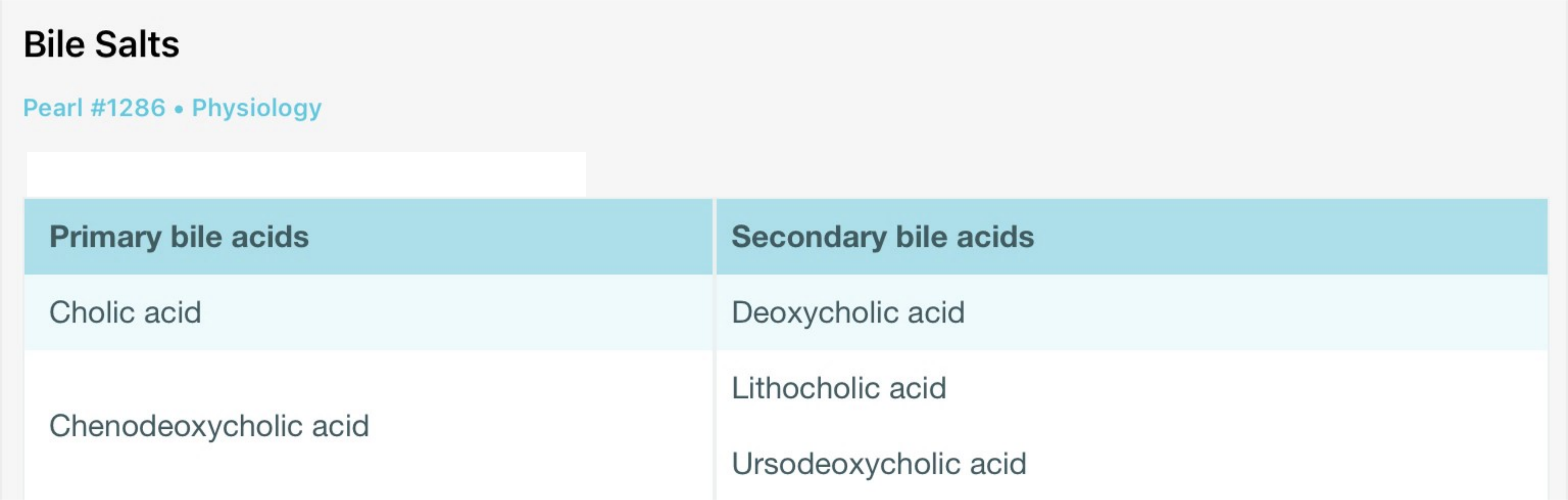
Pearl #1288 • Physiology

Stimuli that increase gastrin secretion
Luminal
Peptides and amino acids
Neural
Increased vagal discharge via GRP
Bloodborne
Ca^{2+} Epinephrine
Stimuli that inhibit gastrin secretion
Luminal
Acid
Somatostatin
Bloodborne
Secretin, GIP, VIP, glucagon, calcitonin



Gastrointestinal Hormones

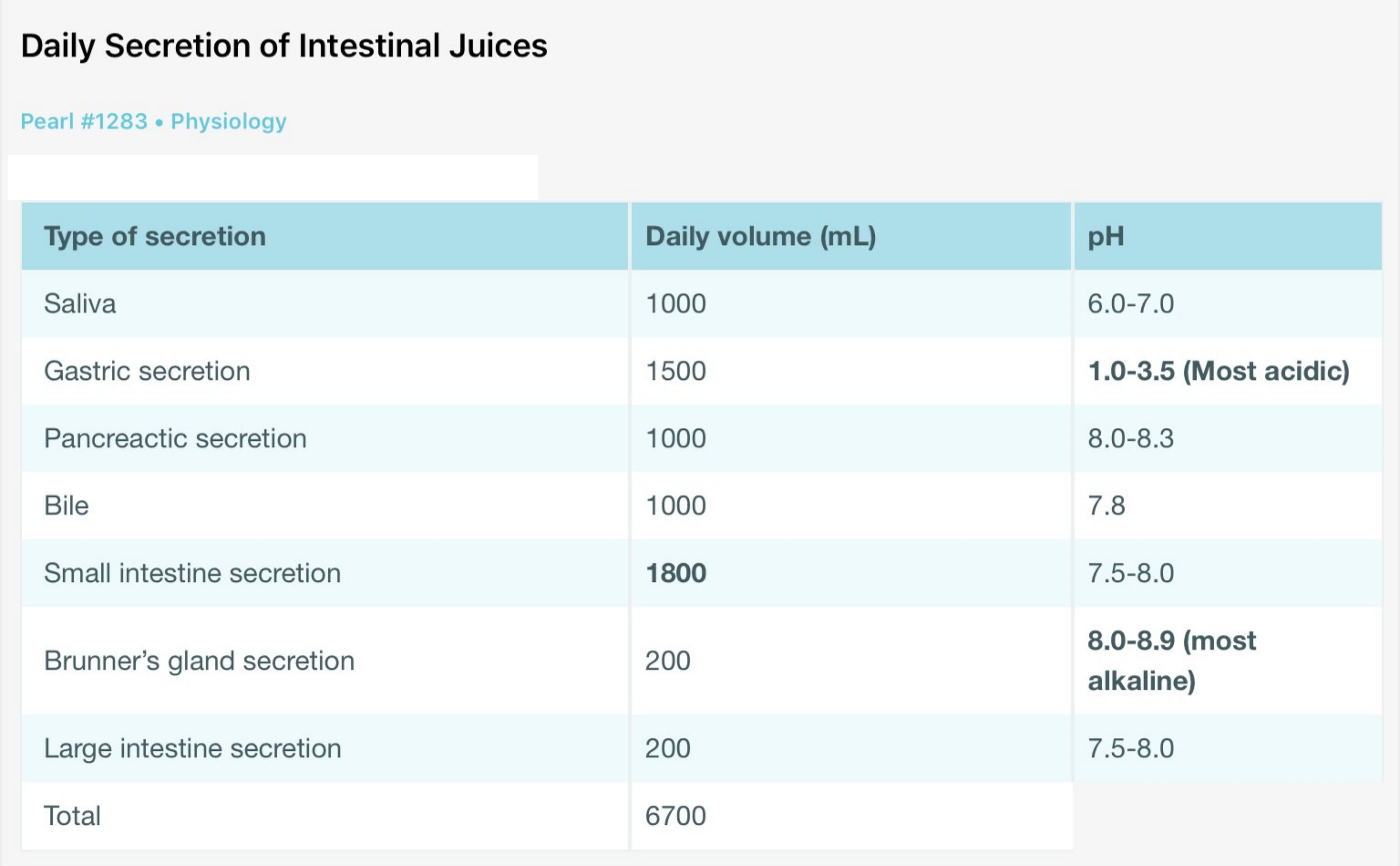
Pearl #1287 • Physiology



Bile Salts

Pearl #1286 • Physiology

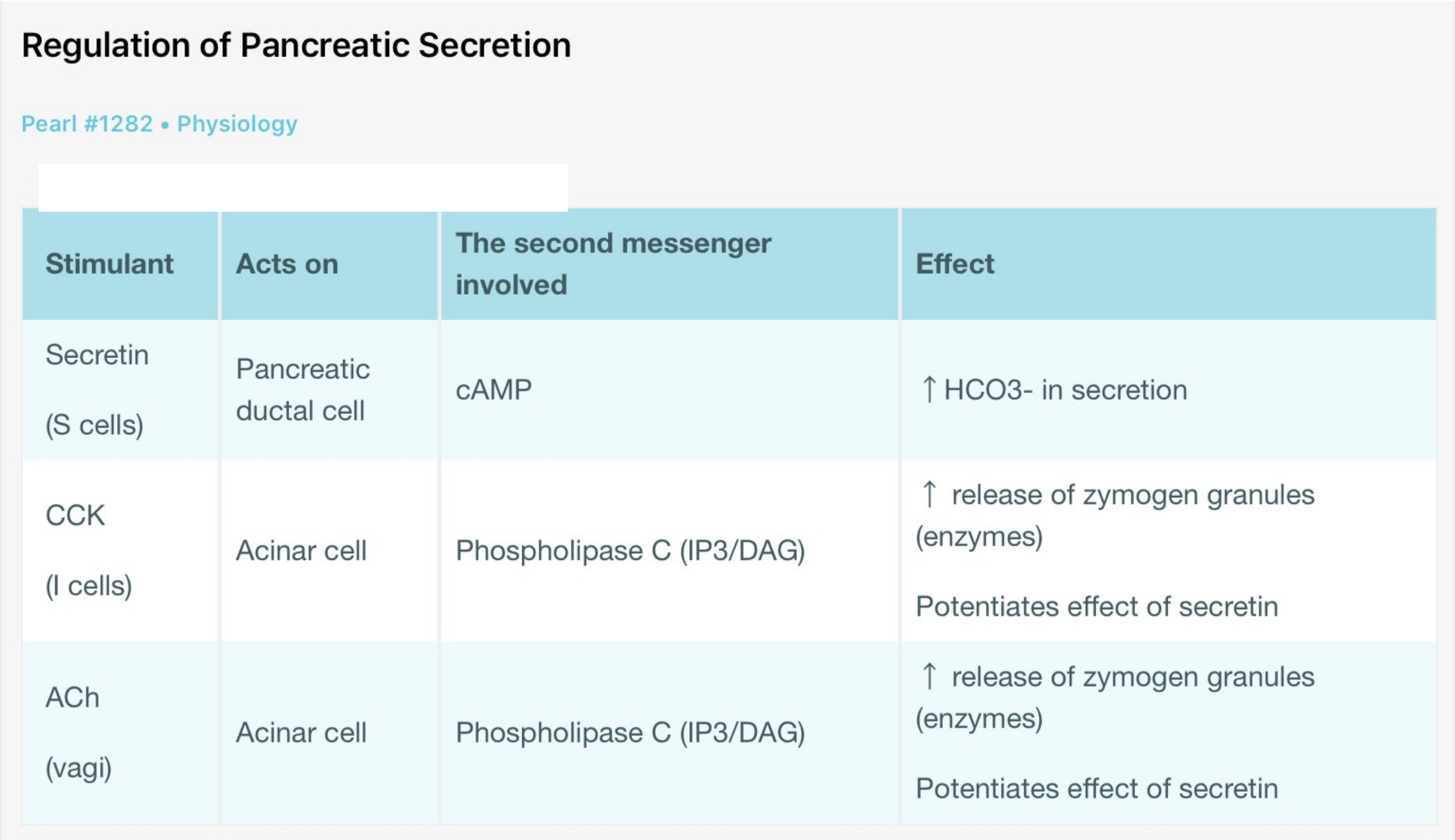
Primary bile acids	Secondary bile acids
Cholic acid	Deoxycholic acid
Chenodeoxycholic acid	Lithocholic acid
	Ursodeoxycholic acid



Daily Secretion of Intestinal Juices

Pearl #1283 • Physiology

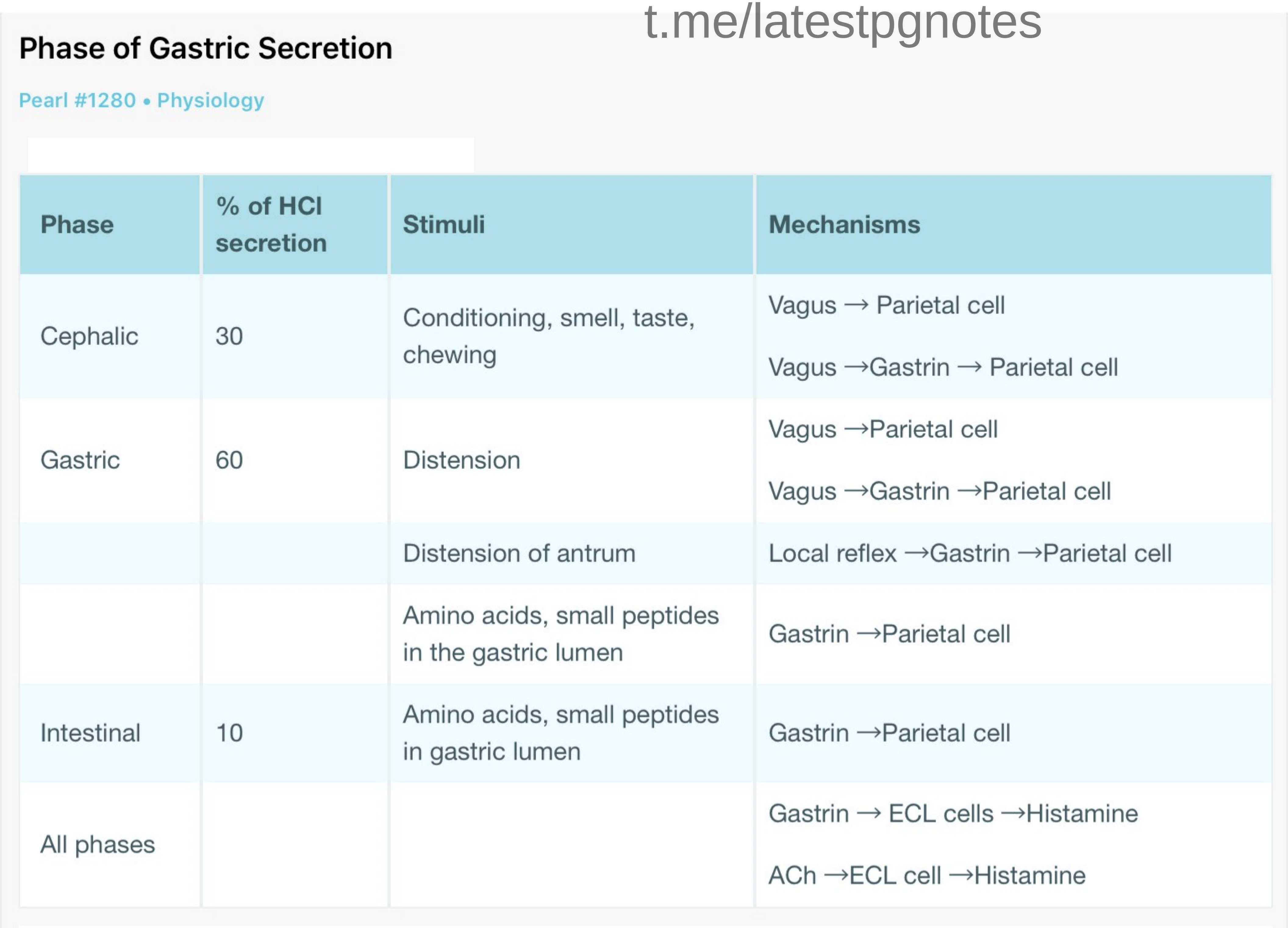
Type of secretion	Daily volume (mL)	pH
Saliva	1000	6.0-7.0
Gastric secretion	1500	**1.0-3.5 (Most acidic)**
Pancreactic secretion	1000	8.0-8.3
Bile	1000	7.8
Small intestine secretion	**1800**	7.5-8.0
Brunner’s gland secretion	200	**8.0-8.9 (most alkaline)**
Large intestine secretion	200	7.5-8.0
Total	6700	



Regulation of Pancreatic Secretion

Pearl #1282 • Physiology

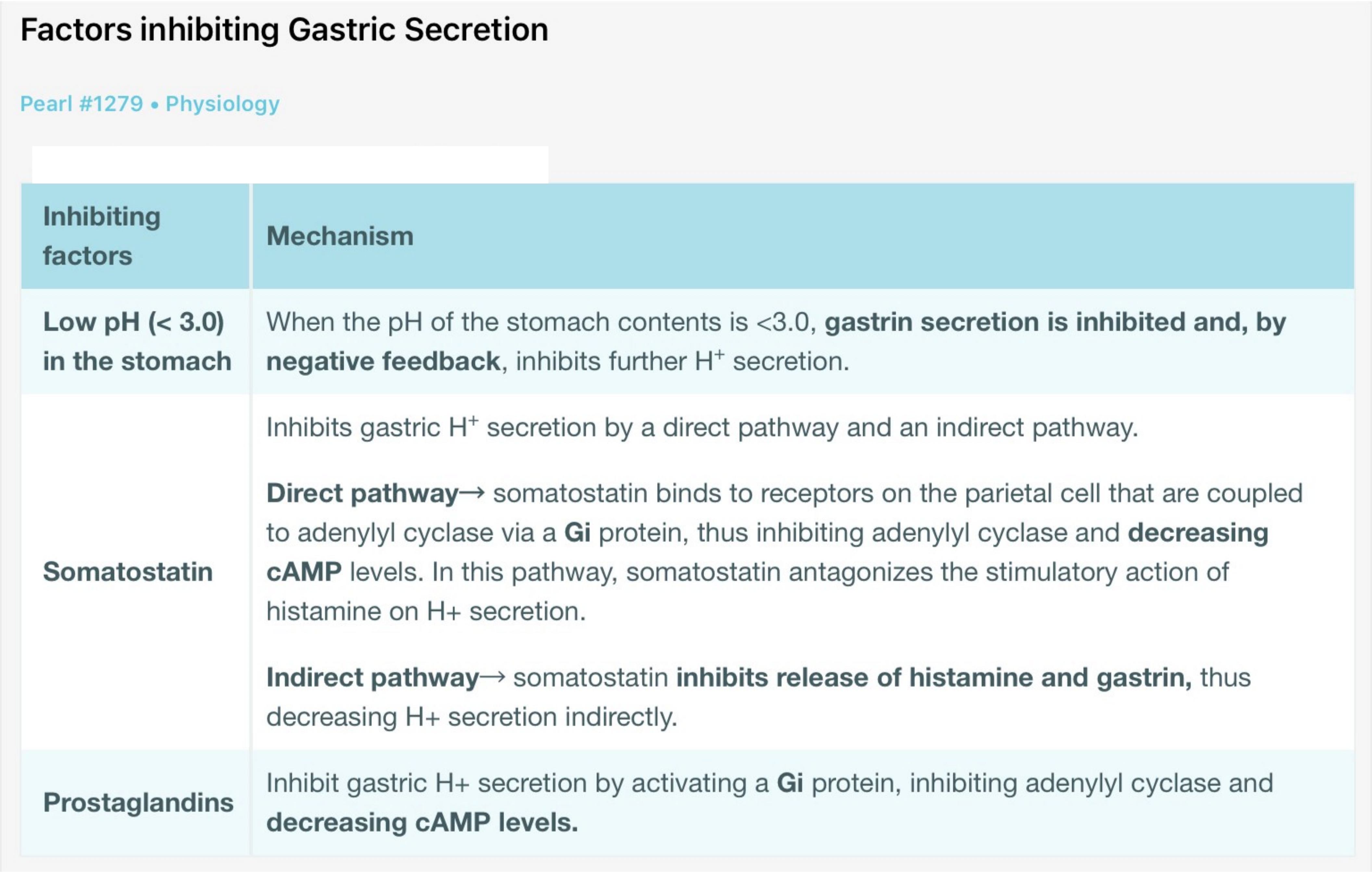
Stimulant	Acts on	The second messenger involved	Effect
Secretin (S cells)	Pancreatic ductal cell	cAMP	↑ HCO3- in secretion
CCK (I cells)	Acinar cell	Phospholipase C (IP3/DAG)	↑ release of zymogen granules (enzymes) Potentiates effect of secretin
ACh (vagi)	Acinar cell	Phospholipase C (IP3/DAG)	↑ release of zymogen granules (enzymes) Potentiates effect of secretin



Phase of Gastric Secretion

Pearl #1280 • Physiology

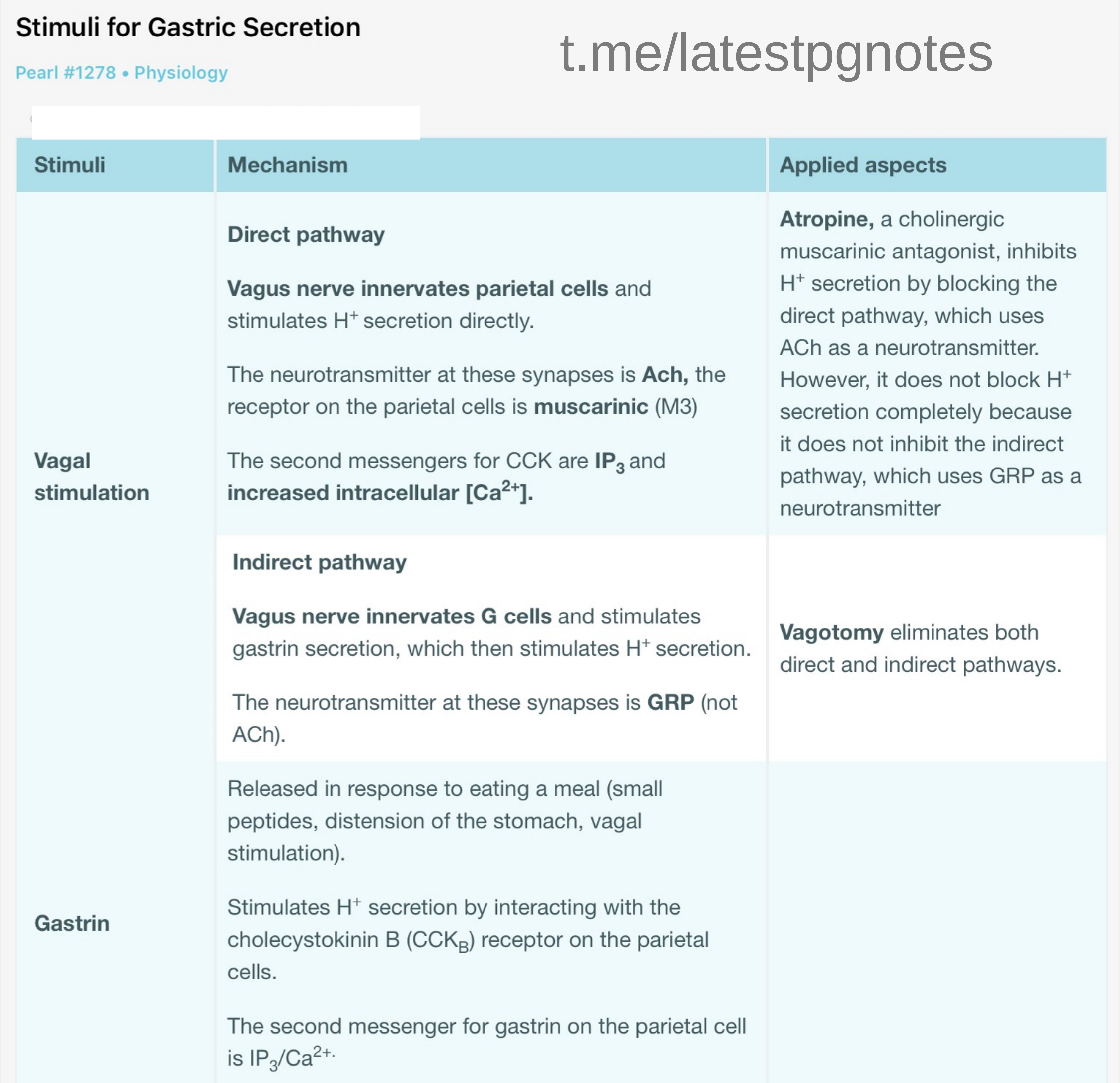
Phase	% of HCl secretion	Stimuli	Mechanisms
Cephalic	30	Conditioning, smell, taste, chewing	Vagus → Parietal cell Vagus →Gastrin → Parietal cell
Gastric	60	Distension	Vagus →Parietal cell Vagus →Gastrin →Parietal cell
		Distension of antrum	Local reflex →Gastrin →Parietal cell
		Amino acids, small peptides in the gastric lumen	Gastrin →Parietal cell
Intestinal	10	Amino acids, small peptides in gastric lumen	Gastrin →Parietal cell
All phases			Gastrin → ECL cells →Histamine ACh →ECL cell →Histamine



Factors inhibiting Gastric Secretion

Pearl #1279 • Physiology

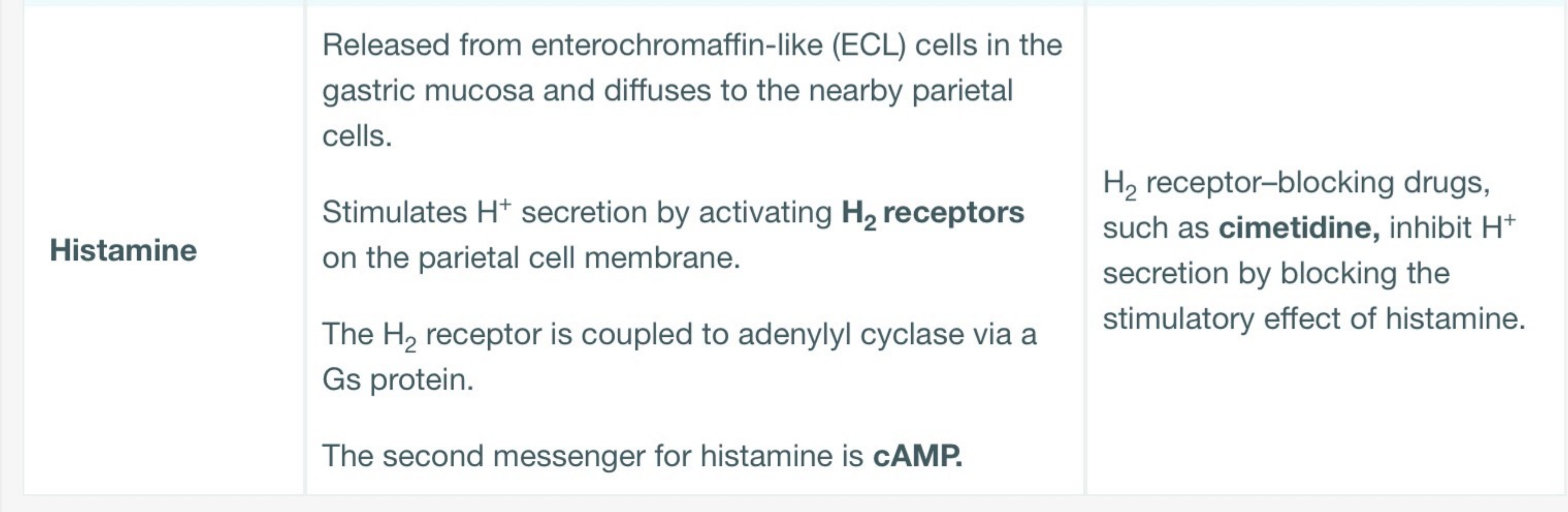
Inhibiting factors	Mechanism
Low pH (< 3.0) in the stomach	When the pH of the stomach contents is <3.0, **gastrin secretion is inhibited and, by negative feedback**, inhibits further H^+ secretion.
Somatostatin	Inhibits gastric H^+ secretion by a direct pathway and an indirect pathway. **Direct pathway**→ somatostatin binds to receptors on the parietal cell that are coupled to adenylyl cyclase via a **Gi** protein, thus inhibiting adenylyl cyclase and **decreasing cAMP** levels. In this pathway, somatostatin antagonizes the stimulatory action of histamine on H+ secretion. **Indirect pathway**→ somatostatin **inhibits release of histamine and gastrin,** thus decreasing H+ secretion indirectly.
Prostaglandins	Inhibit gastric H+ secretion by activating a **Gi** protein, inhibiting adenylyl cyclase and **decreasing cAMP levels.**



Stimuli for Gastric Secretion

Pearl #1278 • Physiology

Stimuli	Mechanism	Applied aspects
Vagal stimulation	**Direct pathway** **Vagus nerve innervates parietal cells** and stimulates H^+ secretion directly. The neurotransmitter at these synapses is **Ach,** the receptor on the parietal cells is **muscarinic** (M3) The second messengers for CCK are **IP_3** and **increased intracellular [Ca^{2+}].**	**Atropine,** a cholinergic muscarinic antagonist, inhibits H^+ secretion by blocking the direct pathway, which uses ACh as a neurotransmitter. However, it does not block H^+ secretion completely because it does not inhibit the indirect pathway, which uses GRP as a neurotransmitter
	Indirect pathway **Vagus nerve innervates G cells** and stimulates gastrin secretion, which then stimulates H^+ secretion. The neurotransmitter at these synapses is **GRP** (not ACh).	**Vagotomy** eliminates both direct and indirect pathways.
Gastrin	Released in response to eating a meal (small peptides, distension of the stomach, vagal stimulation). Stimulates H^+ secretion by interacting with the cholecystokinin B (CCK_B) receptor on the parietal cells. The second messenger for gastrin on the parietal cell is $IP_3/Ca^{2+.}$	

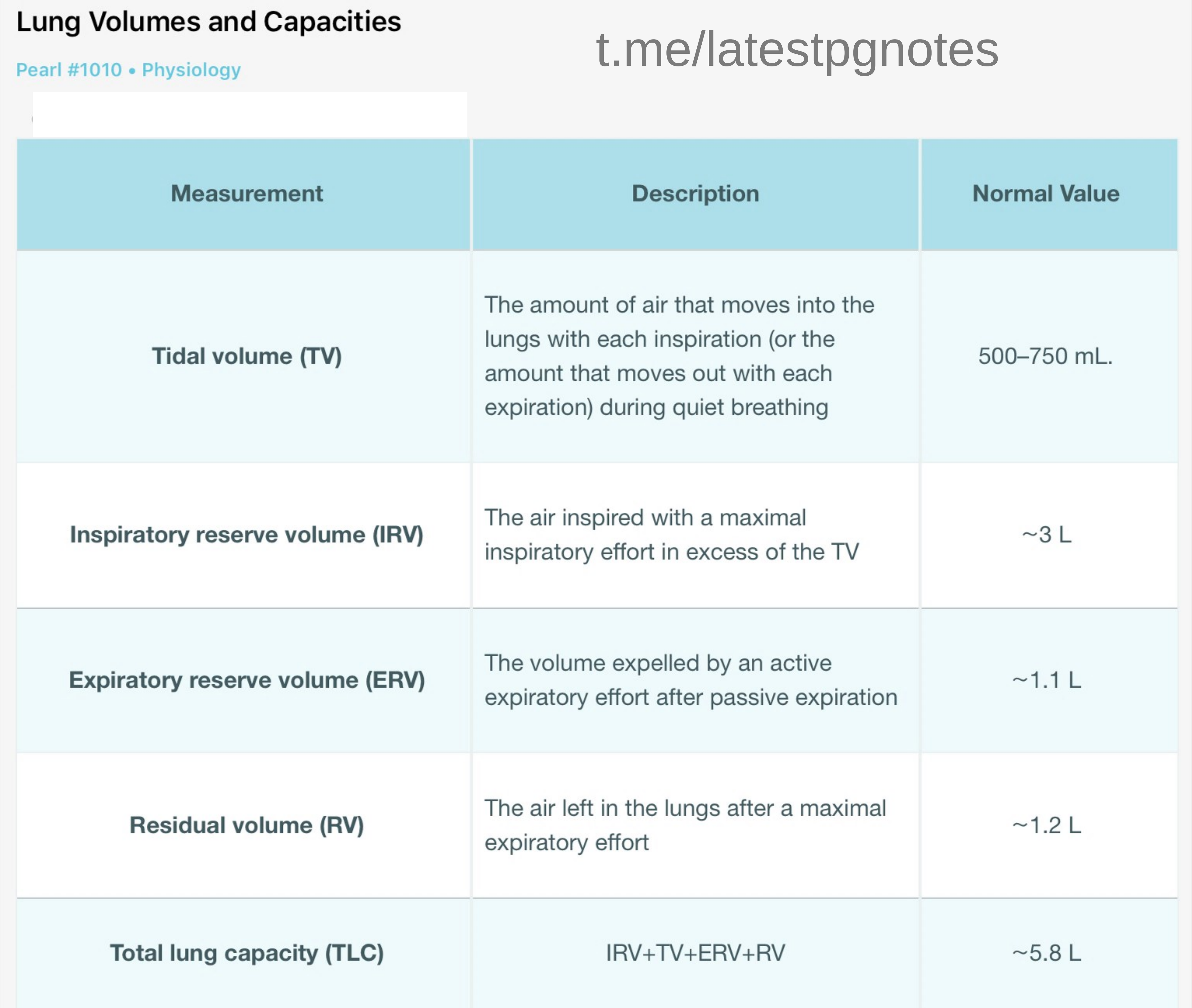


Histamine	Released from enterochromaffin-like (ECL) cells in the gastric mucosa and diffuses to the nearby parietal cells. Stimulates H^+ secretion by activating **H_2 receptors** on the parietal cell membrane. The H_2 receptor is coupled to adenylyl cyclase via a Gs protein. The second messenger for histamine is **cAMP.**	H_2 receptor–blocking drugs, such as **cimetidine,** inhibit H^+ secretion by blocking the stimulatory effect of histamine.

Cells of the Gastric Glands

Pearl #1277 • Physiology

Cell Type	Part of stomach	Secretion	Stimulus for secretion
Parietal cells	Fundus, Body	HCl Intrinsic factor	Gastrin Vagal stimulation (Ach) Histamine
Chief cells	Fundus, Body	Pepsinogen Gastric lipase	Vagal stimulation
Mucous cells	Antrum, cardia, pylorus	Mucous	Vagal stimulation
G cells	Antrum	Gastrin	Vagal stimulation (via GRP) Oligopeptides Inhibited by somatostatin Inhibited by H^+ in stomach
Enterochromaffin cells (ECL)	Fundus	Histamine	Gastrin

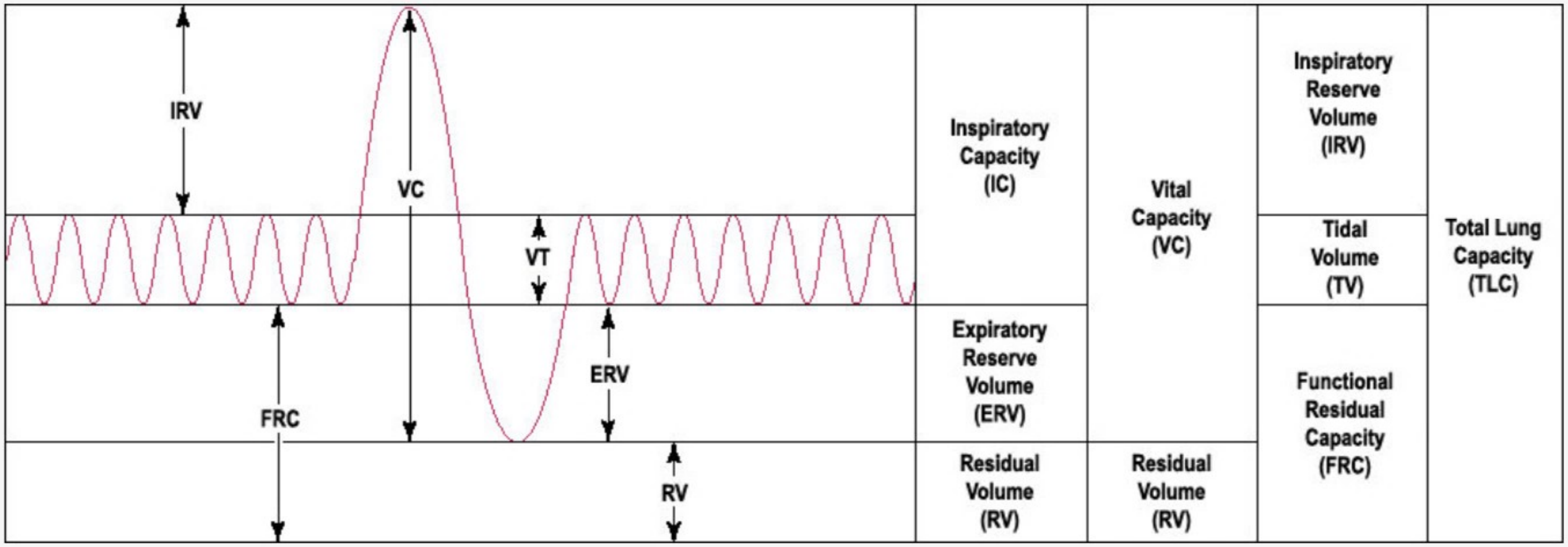


Lung Volumes and Capacities

Pearl #1010 • Physiology

Measurement	Description	Normal Value
Tidal volume (TV)	The amount of air that moves into the lungs with each inspiration (or the amount that moves out with each expiration) during quiet breathing	500–750 mL.
Inspiratory reserve volume (IRV)	The air inspired with a maximal inspiratory effort in excess of the TV	~3 L
Expiratory reserve volume (ERV)	The volume expelled by an active expiratory effort after passive expiration	~1.1 L
Residual volume (RV)	The air left in the lungs after a maximal expiratory effort	~1.2 L
Total lung capacity (TLC)	IRV+TV+ERV+RV	~5.8 L

Total lung capacity (TLC)	IRV+TV+ERV+RV	~5.8 L
Vital capacity (VC)	IRV+TV+ERV	~4.5 L
Inspiratory capacity (IC)	TV+IRV	~3.5 L
Expiratory capacity (EC)	TV+ERV	~1.5 L
Functional residual capacity (FRC)	ERV+RV	~2.3 L


IRV
VC
VT
FRC
ERV
RV
Inspiratory Capacity (IC)
Expiratory Reserve Volume (ERV)
Residual Volume (RV)
Vital Capacity (VC)
Residual Volume (RV)
Inspiratory Reserve Volume (IRV)
Tidal Volume (TV)
Functional Residual Capacity (FRC)
Total Lung Capacity (TLC)

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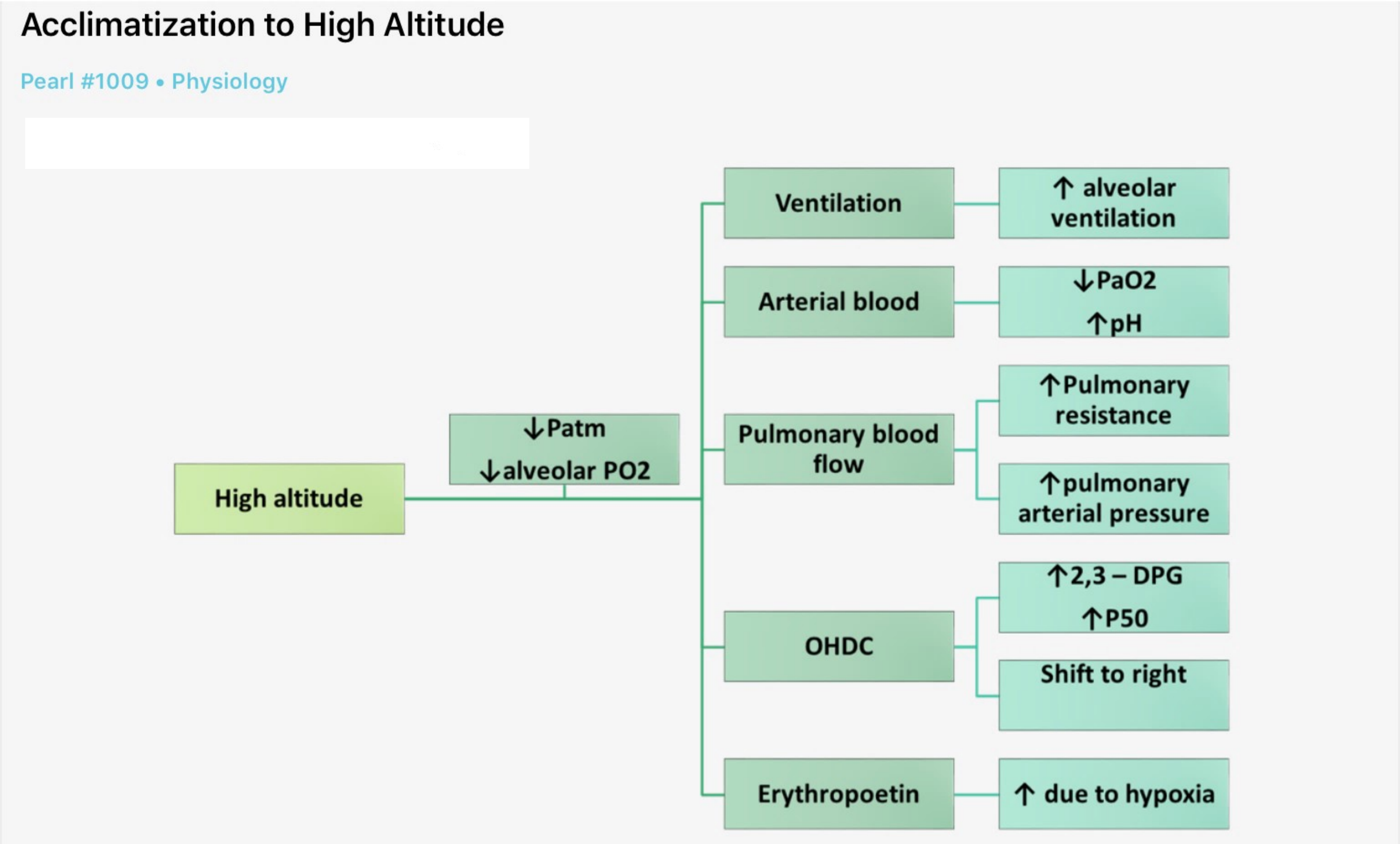


Acclimatization to High Altitude

Pearl #1009 • Physiology

High altitude

↓Patm
↓alveolar PO2

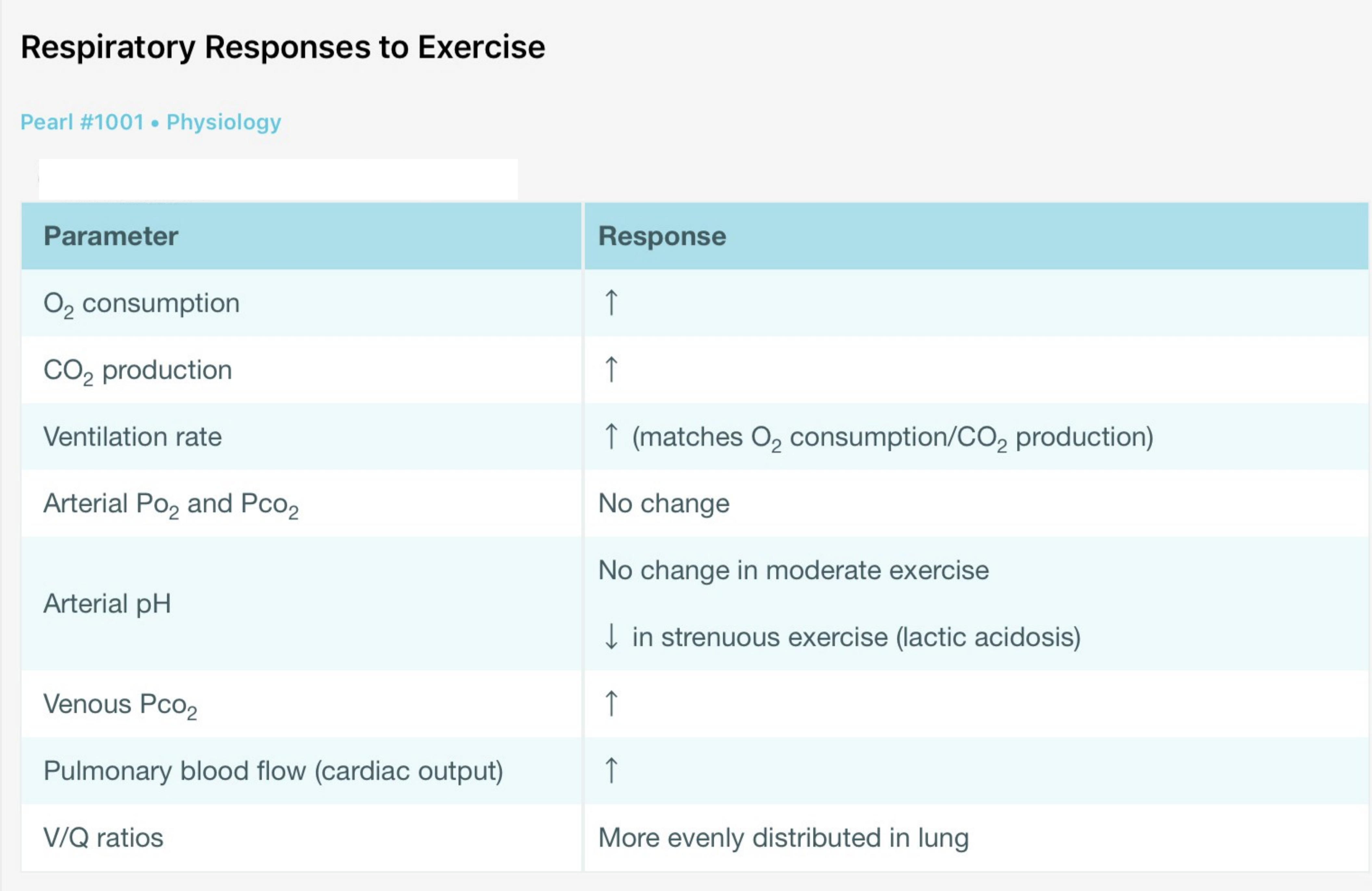
Ventilation
↑ alveolar ventilation

Arterial blood
↓PaO2
↑pH

Pulmonary blood flow
↑Pulmonary resistance
↑pulmonary arterial pressure

OHDC
↑2,3 – DPG
↑P50
Shift to right

Erythropoetin
↑ due to hypoxia



Respiratory Responses to Exercise

Pearl #1001 • Physiology

Parameter	Response
O_2 consumption	↑
CO_2 production	↑
Ventilation rate	↑ (matches O_2 consumption/CO_2 production)
Arterial Po_2 and Pco_2	No change
Arterial pH	No change in moderate exercise ↓ in strenuous exercise (lactic acidosis)
Venous Pco_2	↑
Pulmonary blood flow (cardiac output)	↑
V/Q ratios	More evenly distributed in lung

Effects of Various Lesions and Brainstem Transections

Pearl #998 • Physiology

Label	Level of transection	Vagi intact	Vagi cut
A	Complete transection above pons	Regular breathing continues	Regular breathing continues but depth of inspiration increases
B	Mid-pontine level section	Regular breathing continues	Apneusis develops
C	Transection midway between pons and medulla	Irregular but rhythmic respiration	Irregular but rhythmic respiration
D	Complete transection below medulla	Spontaneous respiration ceases	Spontaneous respiration ceases

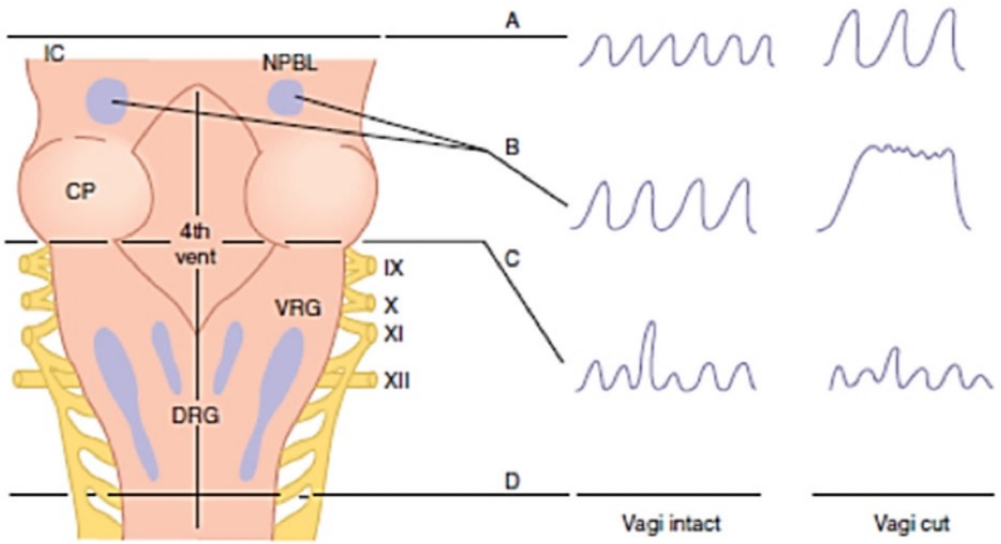
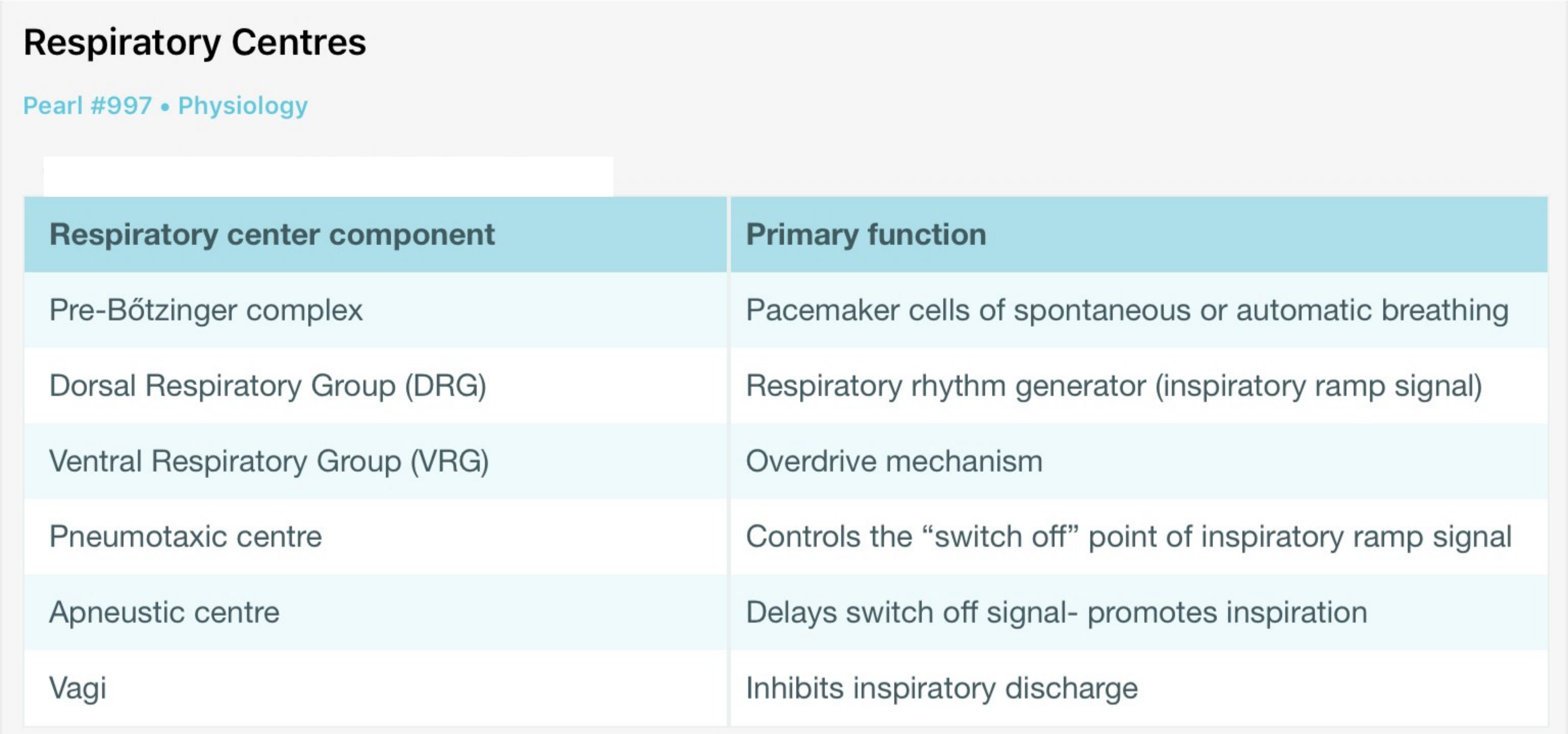


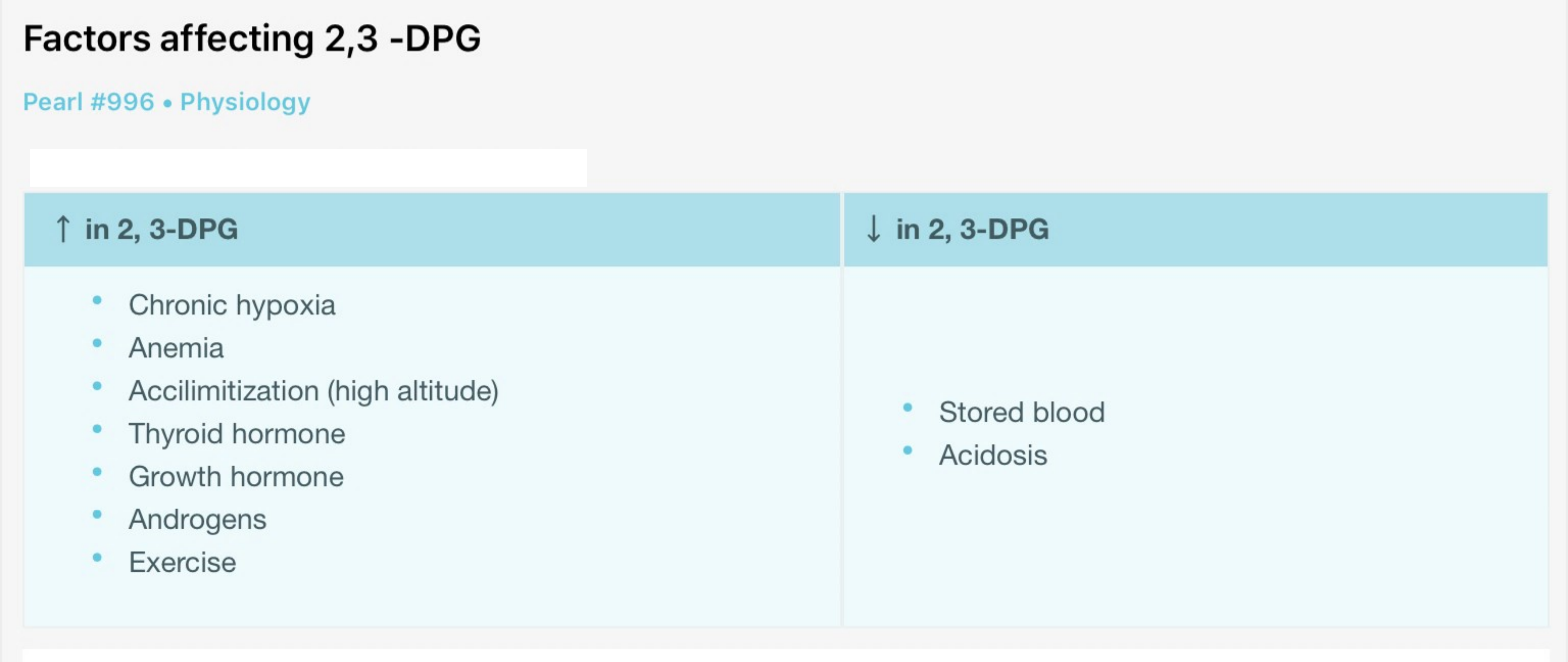
FIGURE 36–2 **Respiratory neurons in the brain stem.** Dorsal view of brain stem; cerebellum removed. The effects of various lesions and brain stem transections are shown; the spirometer tracings at the right indicate the depth and rate of breathing. If a lesion is introduced at D, breathing ceases. The effects of higher transections, with and without vagus nerves transection, are shown (see text for details). CP, middle cerebellar peduncle; DRG, dorsal group of respiratory neurons; IC, inferior colliculus; NPBL, nucleus parabrachialis (pneumotaxic center); VRG, ventral group of respiratory neurons; 4th vent, fourth ventricle. The roman numerals identify cranial nerves. (Modified from Mitchell RA, Berger A: State of the art: Review of neural regulation of respiration. Am Rev Respir Dis 1975;111:206.)



Respiratory Centres

Pearl #997 • Physiology

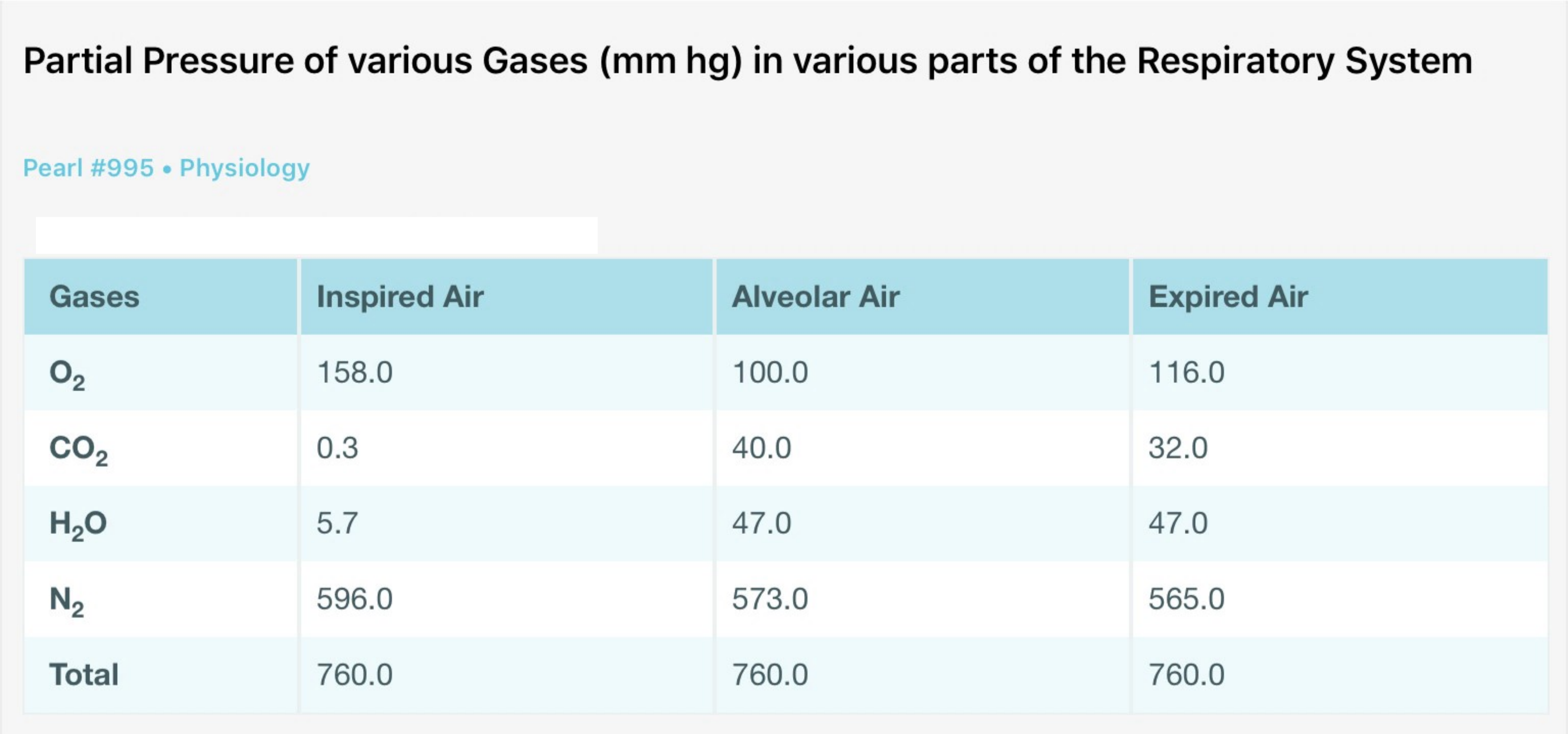
Respiratory center component	Primary function
Pre-Bőtzinger complex	Pacemaker cells of spontaneous or automatic breathing
Dorsal Respiratory Group (DRG)	Respiratory rhythm generator (inspiratory ramp signal)
Ventral Respiratory Group (VRG)	Overdrive mechanism
Pneumotaxic centre	Controls the “switch off” point of inspiratory ramp signal
Apneustic centre	Delays switch off signal- promotes inspiration
Vagi	Inhibits inspiratory discharge



Factors affecting 2,3 -DPG

Pearl #996 • Physiology

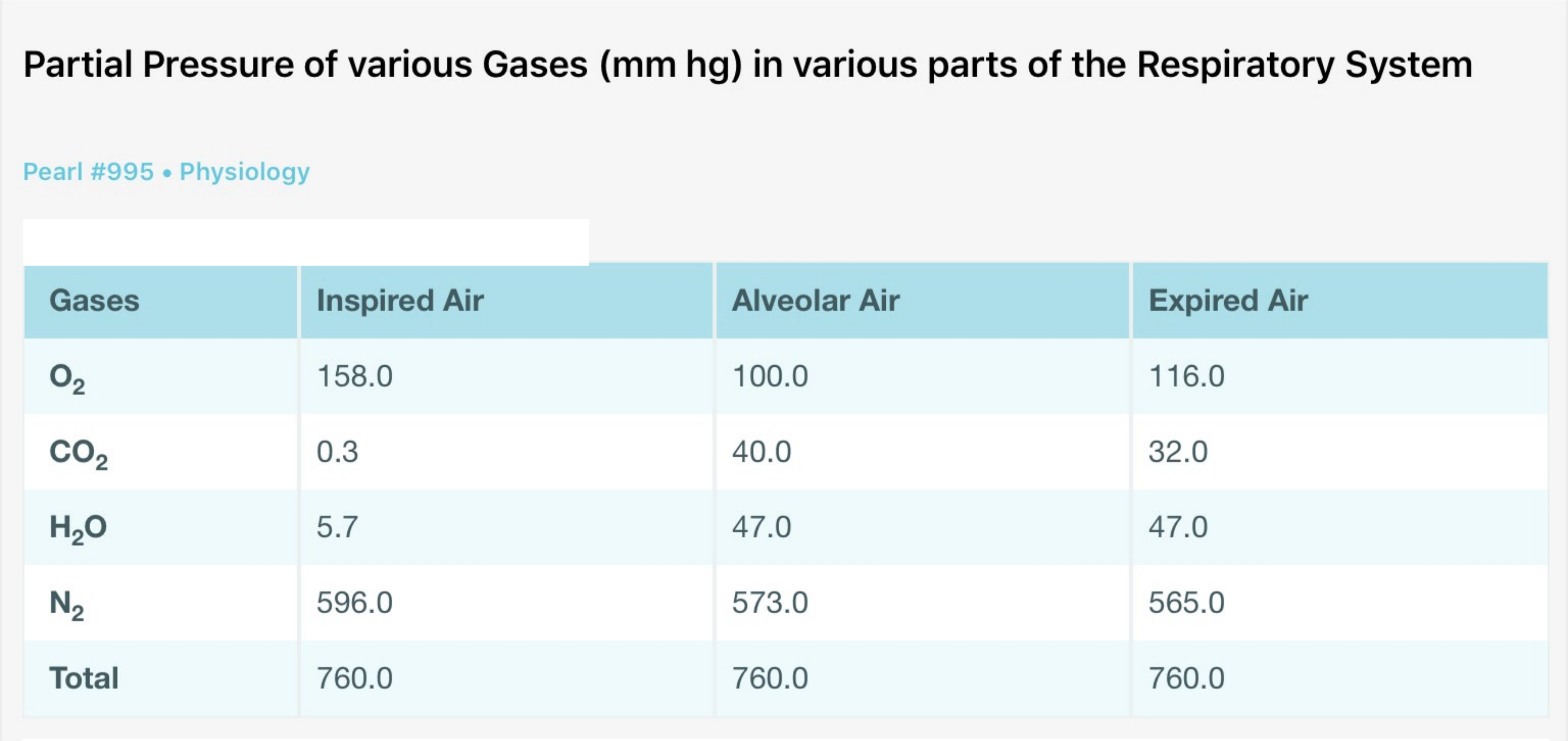
↑ in 2, 3-DPG	↓ in 2, 3-DPG
Chronic hypoxia Anemia Accilimitization (high altitude) Thyroid hormone Growth hormone Androgens Exercise	Stored blood Acidosis



Partial Pressure of various Gases (mm hg) in various parts of the Respiratory System

Pearl #995 • Physiology

Gases	Inspired Air	Alveolar Air	Expired Air
O_2	158.0	100.0	116.0
CO_2	0.3	40.0	32.0
H_2O	5.7	47.0	47.0
N_2	596.0	573.0	565.0
Total	760.0	760.0	760.0



Partial Pressure of various Gases (mm hg) in various parts of the Respiratory System

Pearl #995 • Physiology

Gases	Inspired Air	Alveolar Air	Expired Air
O_2	158.0	100.0	116.0
CO_2	0.3	40.0	32.0
H_2O	5.7	47.0	47.0
N_2	596.0	573.0	565.0
Total	760.0	760.0	760.0

Physical Laws applicable in Respiratory Physiology

Pearl #993 • Physiology

Boyle's law:

- At a given temperature, the product of pressure times volume for a gas is constant
- PV=nRT

Charles law:

- At constant pressure, the volume occupied by a fixed mass of gas is proportional to temperature
- V/T = constant

Dalton's Law:

- It states that the partial pressure of a gas in a mixture of gases is the pressure that gas would exert if it occupied the total volume of the mixture.
- Partial pressure is the total pressure multiplied by the fractional concentration of dry gas.

Henry's Law:

- The amount of gas dissolved is directly proportional to the partial pressure of the gas with which it is in equilibrium.

Graham's Law:

- The rate of diffusion of a gas is inversely proportional to molecular weight.

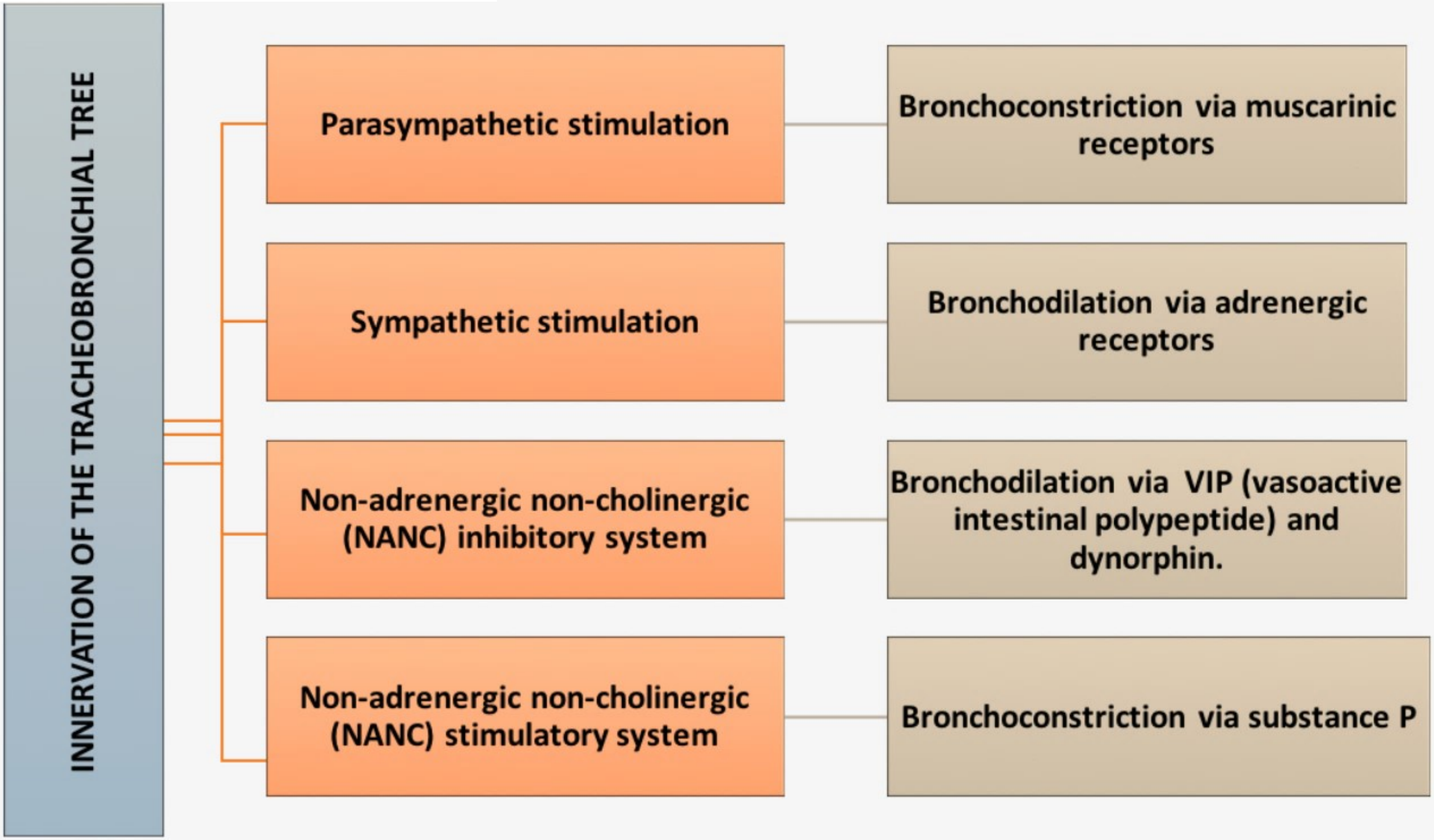
Biologically Active Substances Metabolized by the Lungs

Pearl #985 • Physiology

Synthesized and used in the lungs
Surfactant
Synthesized or stored and released into the blood
Prostaglandins
Histamine
Kallikrein
Partially removed from the blood
Prostaglandins
Bradykinin
Adenine nucleotides
Serotonin
Norepinephrine
Acetylcholine
Activated in the lungs
Angiotensin I → Angiotensin II

Innervation of Tracheobronchial Tree

Pearl #984 • Physiology



INNERVATION OF THE TRACHEOBRONCHIAL TREE

Parasympathetic stimulation	Bronchoconstriction via muscarinic receptors
Sympathetic stimulation	Bronchodilation via adrenergic receptors
Non-adrenergic non-cholinergic (NANC) inhibitory system	Bronchodilation via VIP (vasoactive intestinal polypeptide) and dynorphin.
Non-adrenergic non-cholinergic (NANC) stimulatory system	Bronchoconstriction via substance P

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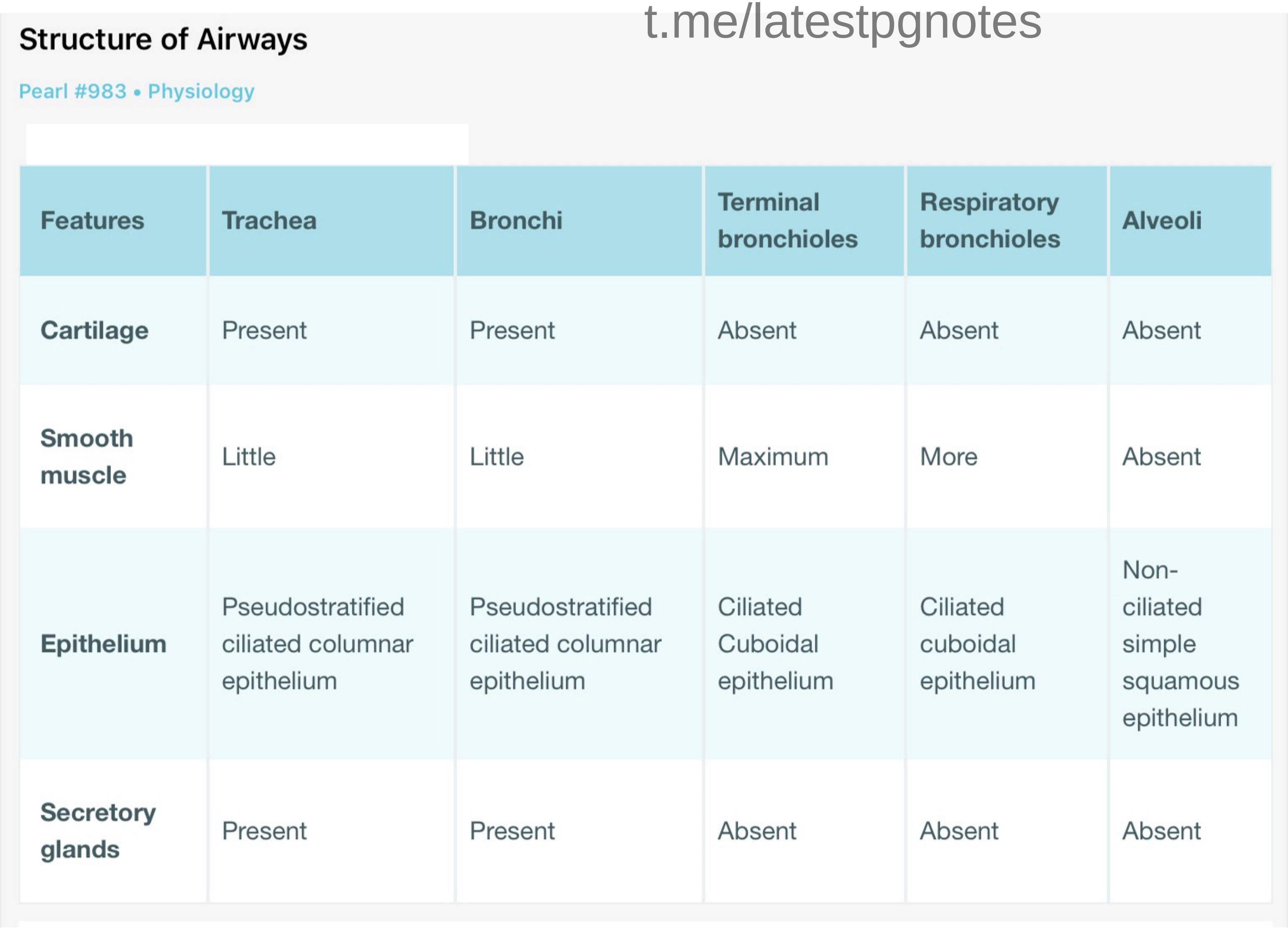


Structure of Airways

Pearl #983 • Physiology

Features	Trachea	Bronchi	Terminal bronchioles	Respiratory bronchioles	Alveoli
Cartilage	Present	Present	Absent	Absent	Absent
Smooth muscle	Little	Little	Maximum	More	Absent
Epithelium	Pseudostratified ciliated columnar epithelium	Pseudostratified ciliated columnar epithelium	Ciliated Cuboidal epithelium	Ciliated cuboidal epithelium	Non-ciliated simple squamous epithelium
Secretory glands	Present	Present	Absent	Absent	Absent

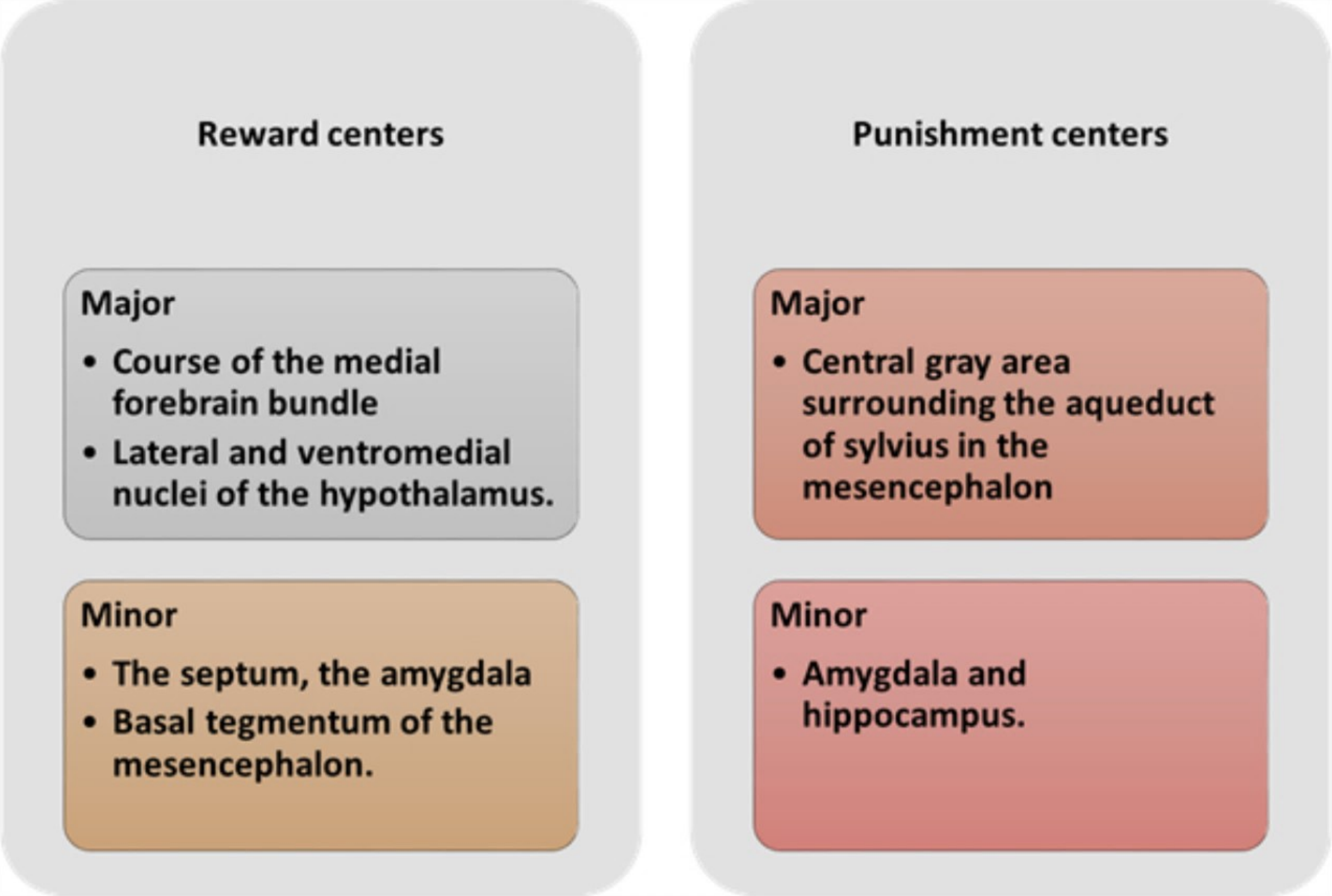
Functions of hypothalamus

Pearl #922 • Physiology

- **Ventromedial**
  - Satiety
- **Arcuate**
  - Either increase or decrease appetite
- **Paraventricular nucleus**
  - Oxytocin release
  - Satiety
  - ACTH and beta lipotropin and blood pressure
- **Medial Preoptic and anterior hypothalamus**
  - Body temperature regulation -
    Anterior: responds to heat
    Posterior: responds to cold
  - Sweating
- **Supra optic**
  - Vasopressin
- **Preoptic**
  - FSH and LH via GRH
- **Anterior hypothalamus**
  - Osmoreceptor
- **Lateral hypothalamus**
  - Hunger

Reward and punishment centers in brain

Pearl #921 • Physiology



Reward centers

Major

- Course of the medial forebrain bundle
- Lateral and ventromedial nuclei of the hypothalamus.

Minor

- The septum, the amygdala
- Basal tegmentum of the mesencephalon.

Punishment centers

Major

- Central gray area surrounding the aqueduct of sylvius in the mesencephalon

Minor

- Amygdala and hippocampus.

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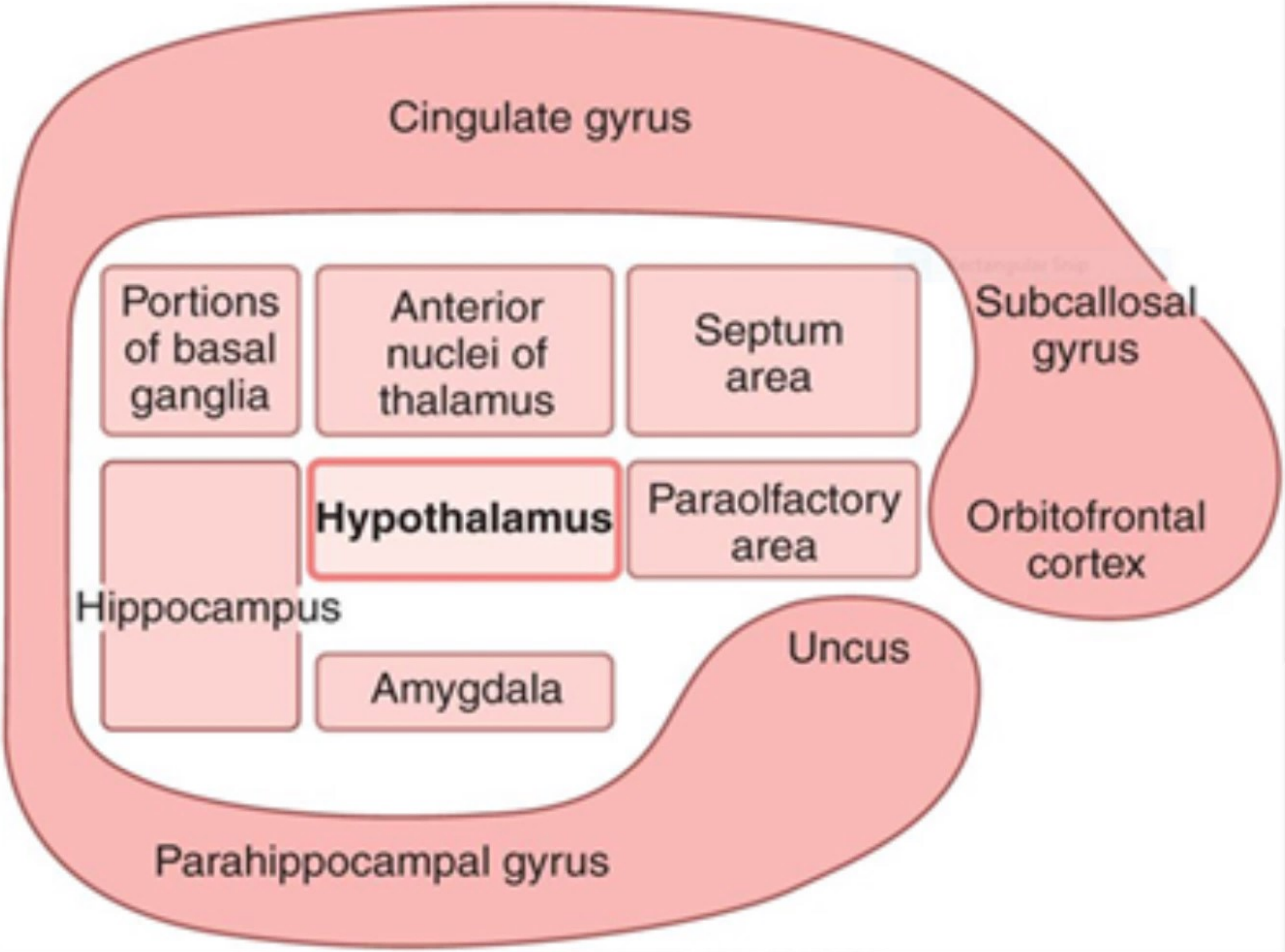
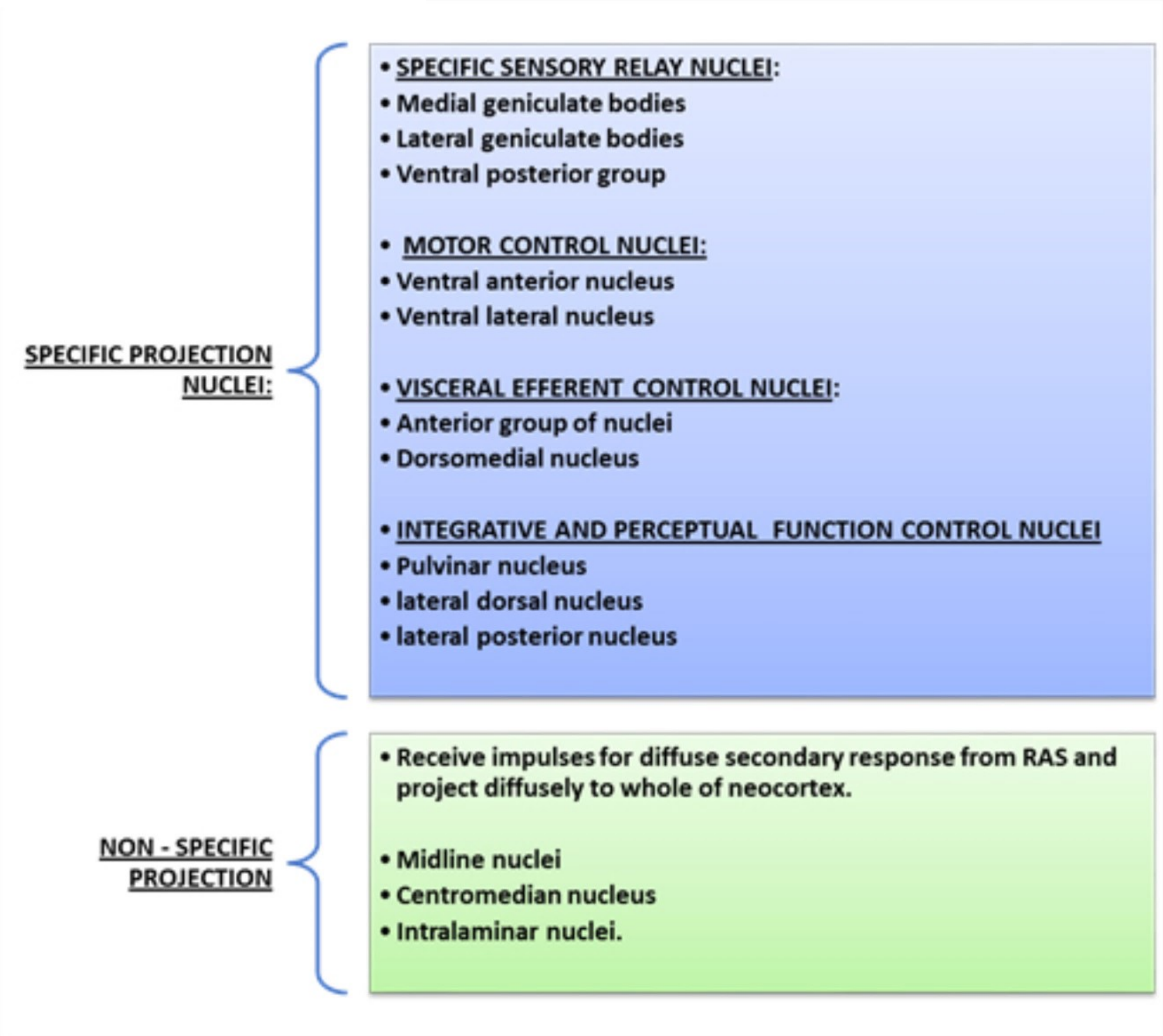
Components of limbic system

Pearl #920 • Physiology



Divisions of thalamic nuclei

Pearl #919 • Physiology



SPECIFIC PROJECTION NUCLEI:

- **SPECIFIC SENSORY RELAY NUCLEI:**
- Medial geniculate bodies
- Lateral geniculate bodies
- Ventral posterior group

- **MOTOR CONTROL NUCLEI:**
- Ventral anterior nucleus
- Ventral lateral nucleus

- **VISCERAL EFFERENT CONTROL NUCLEI:**
- Anterior group of nuclei
- Dorsomedial nucleus

- **INTEGRATIVE AND PERCEPTUAL FUNCTION CONTROL NUCLEI**
- Pulvinar nucleus
- lateral dorsal nucleus
- lateral posterior nucleus

NON - SPECIFIC PROJECTION

- Receive impulses for diffuse secondary response from RAS and project diffusely to whole of neocortex.

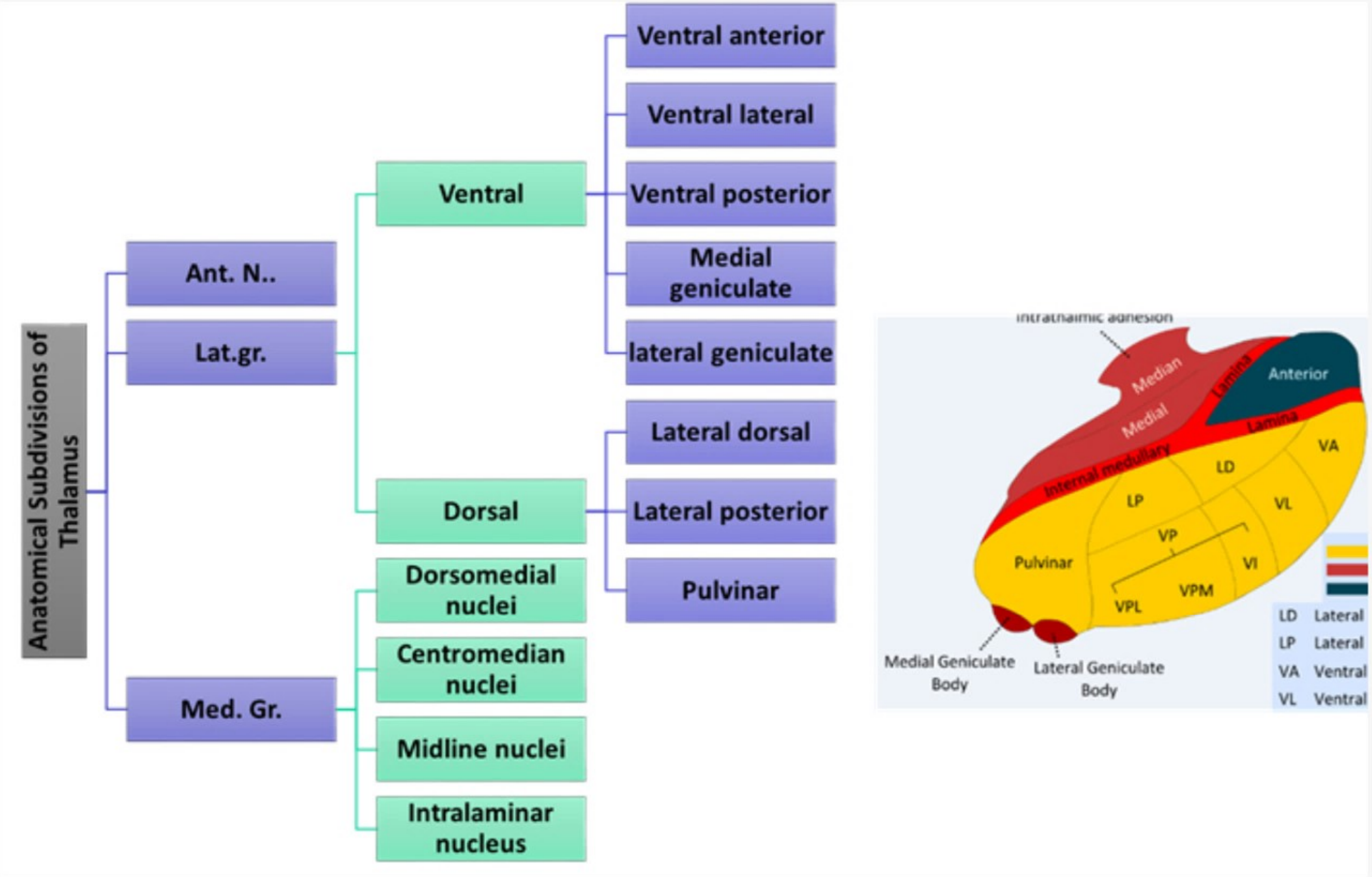
- Midline nuclei
- Centromedian nucleus
- Intralaminar nuclei.

Divisions of thalamus

Pearl #918 • Physiology

Three major divisions

- Anterior group
- Medial group
- Lateral group



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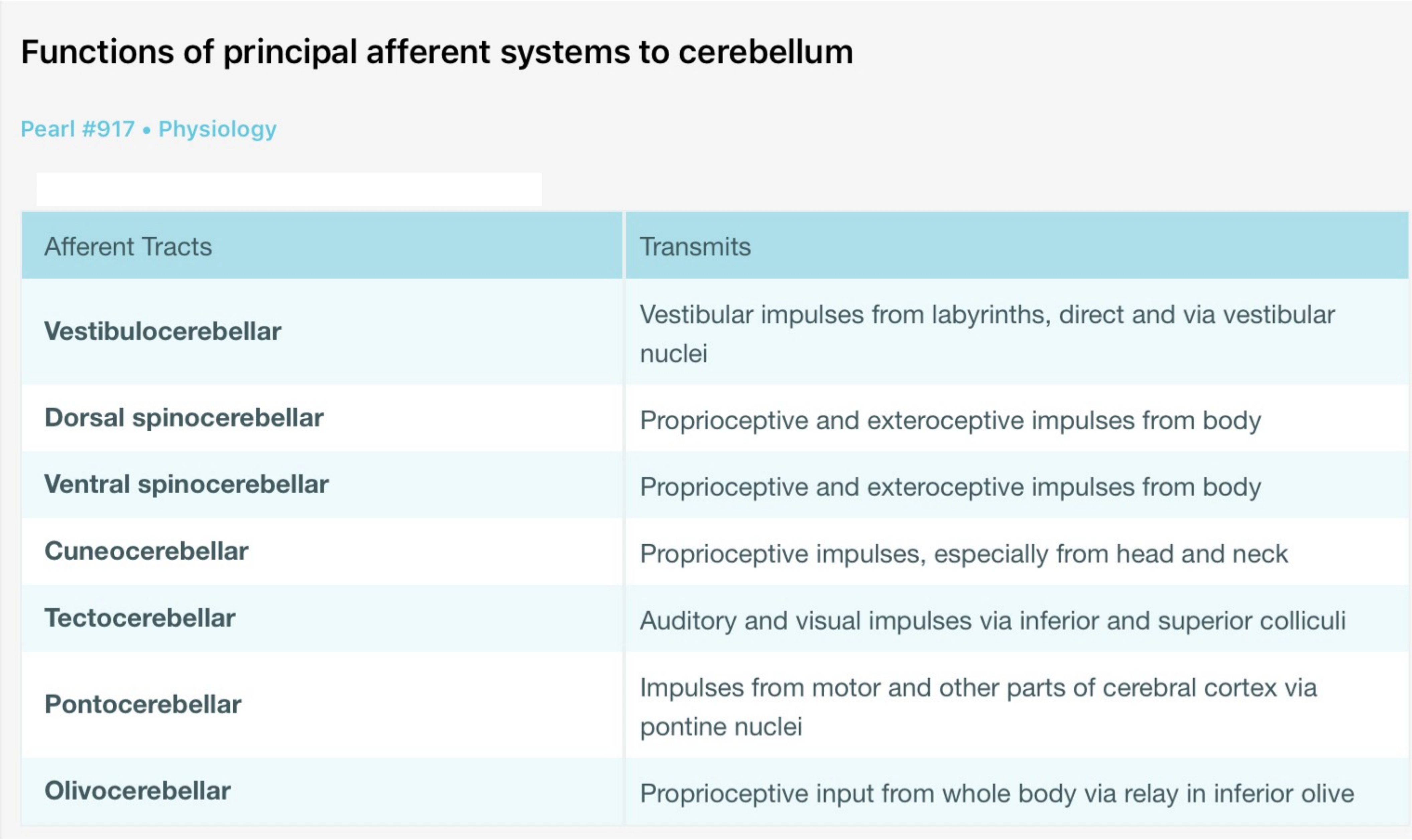
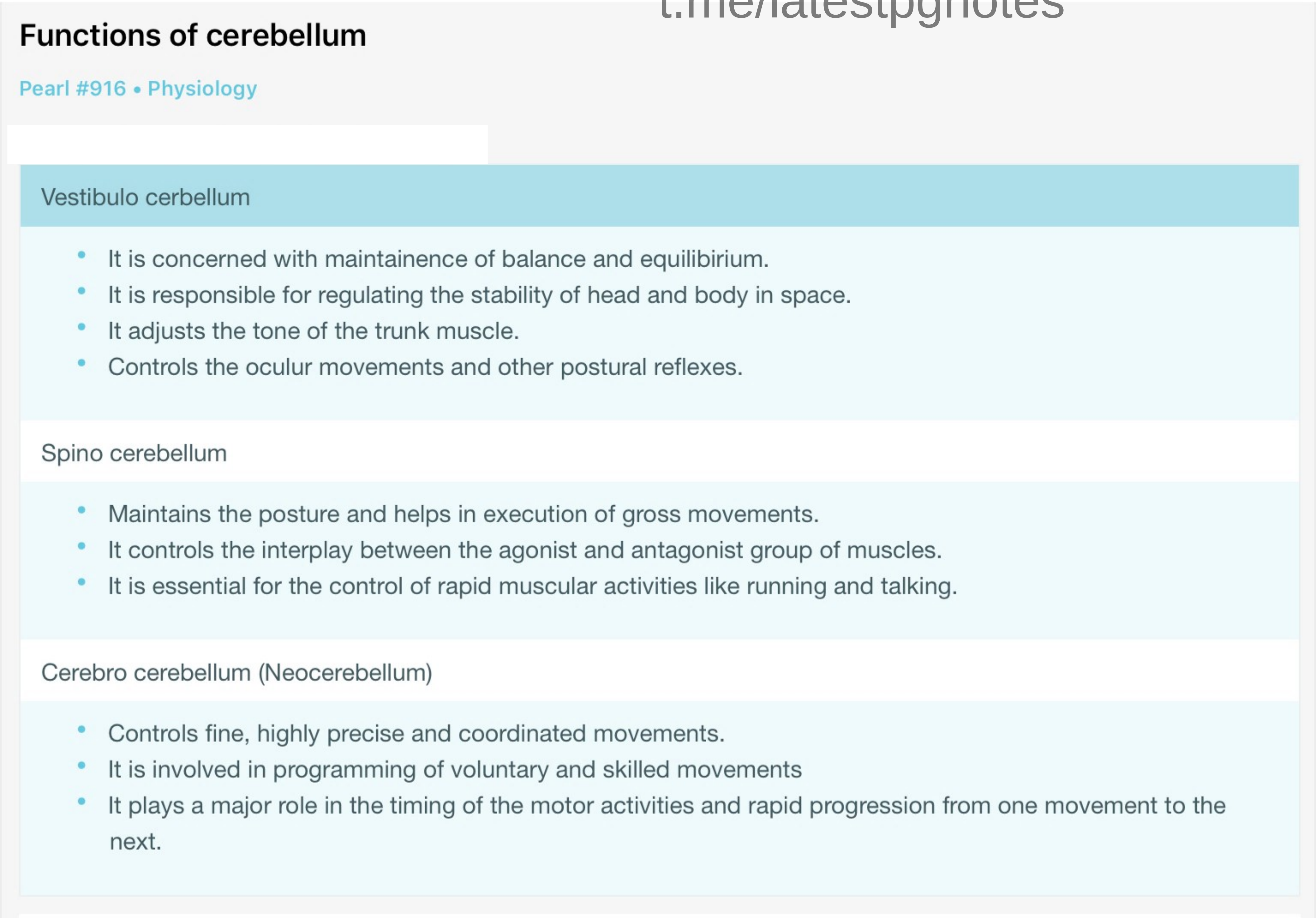


Functions of principal afferent systems to cerebellum

Pearl #917 • Physiology

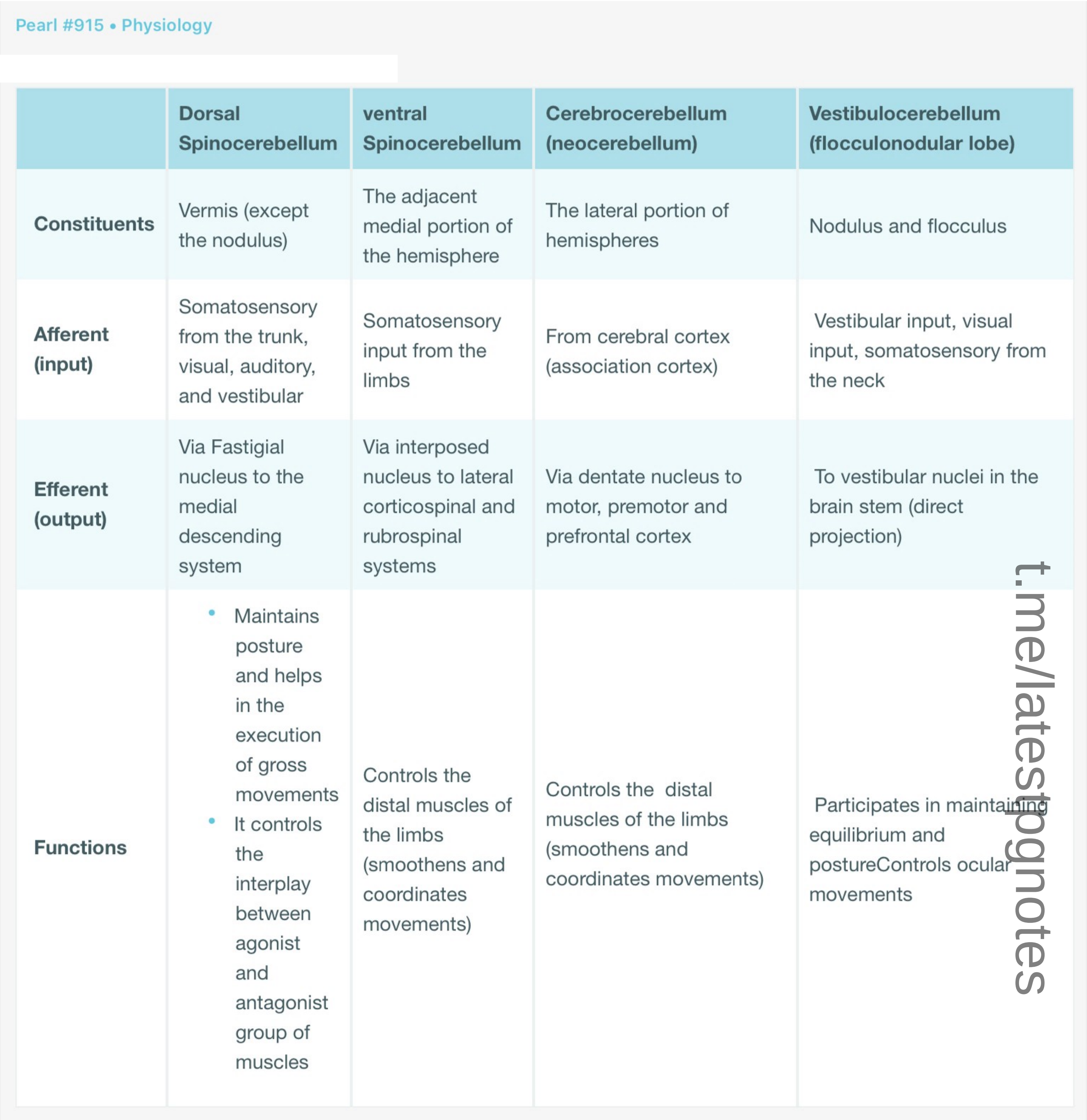
Afferent Tracts	Transmits
Vestibulocerebellar	Vestibular impulses from labyrinths, direct and via vestibular nuclei
Dorsal spinocerebellar	Proprioceptive and exteroceptive impulses from body
Ventral spinocerebellar	Proprioceptive and exteroceptive impulses from body
Cuneocerebellar	Proprioceptive impulses, especially from head and neck
Tectocerebellar	Auditory and visual impulses via inferior and superior colliculi
Pontocerebellar	Impulses from motor and other parts of cerebral cortex via pontine nuclei
Olivocerebellar	Proprioceptive input from whole body via relay in inferior olive



Functions of cerebellum

Pearl #916 • Physiology

Vestibulo cerbellum
It is concerned with maintainence of balance and equilibirium. It is responsible for regulating the stability of head and body in space. It adjusts the tone of the trunk muscle. Controls the oculur movements and other postural reflexes.
Spino cerebellum
Maintains the posture and helps in execution of gross movements. It controls the interplay between the agonist and antagonist group of muscles. It is essential for the control of rapid muscular activities like running and talking.
Cerebro cerebellum (Neocerebellum)
Controls fine, highly precise and coordinated movements. It is involved in programming of voluntary and skilled movements It plays a major role in the timing of the motor activities and rapid progression from one movement to the next.



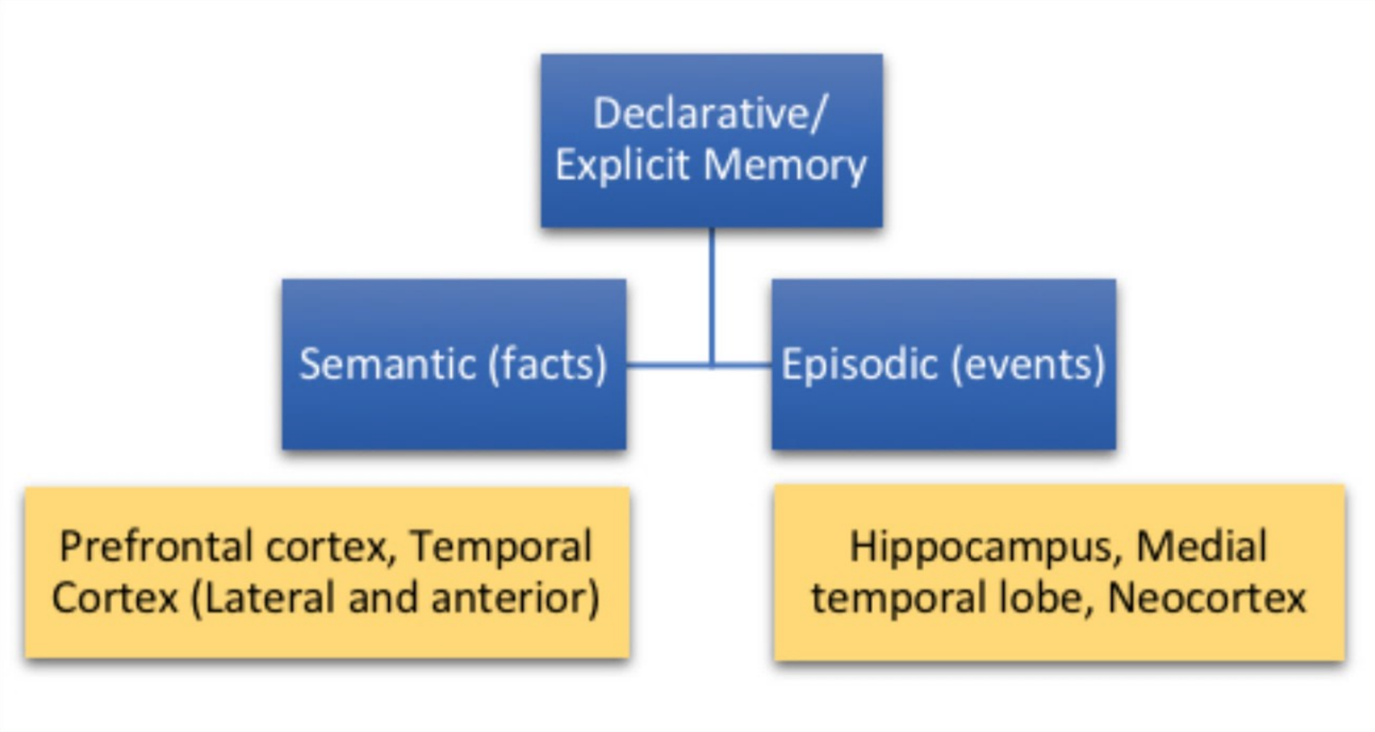
Pearl #915 • Physiology

	Dorsal Spinocerebellum	ventral Spinocerebellum	Cerebrocerebellum (neocerebellum)	Vestibulocerebellum (flocculonodular lobe)
Constituents	Vermis (except the nodulus)	The adjacent medial portion of the hemisphere	The lateral portion of hemispheres	Nodulus and flocculus
Afferent (input)	Somatosensory from the trunk, visual, auditory, and vestibular	Somatosensory input from the limbs	From cerebral cortex (association cortex)	Vestibular input, visual input, somatosensory from the neck
Efferent (output)	Via Fastigial nucleus to the medial descending system	Via interposed nucleus to lateral corticospinal and rubrospinal systems	Via dentate nucleus to motor, premotor and prefrontal cortex	To vestibular nuclei in the brain stem (direct projection)
Functions	• Maintains posture and helps in the execution of gross movements • It controls the interplay between agonist and antagonist group of muscles	Controls the distal muscles of the limbs (smoothens and coordinates movements)	Controls the distal muscles of the limbs (smoothens and coordinates movements)	Participates in maintaining equilibrium and postureControls ocular movements

Forms of Memory

Pearl #907 • Physiology

From physiologic point of view memory is divided into explicit and implicit forms.


Declarative/ Explicit Memory
Semantic (facts)
Episodic (events)
Prefrontal cortex, Temporal Cortex (Lateral and anterior)
Hippocampus, Medial temporal lobe, Neocortex

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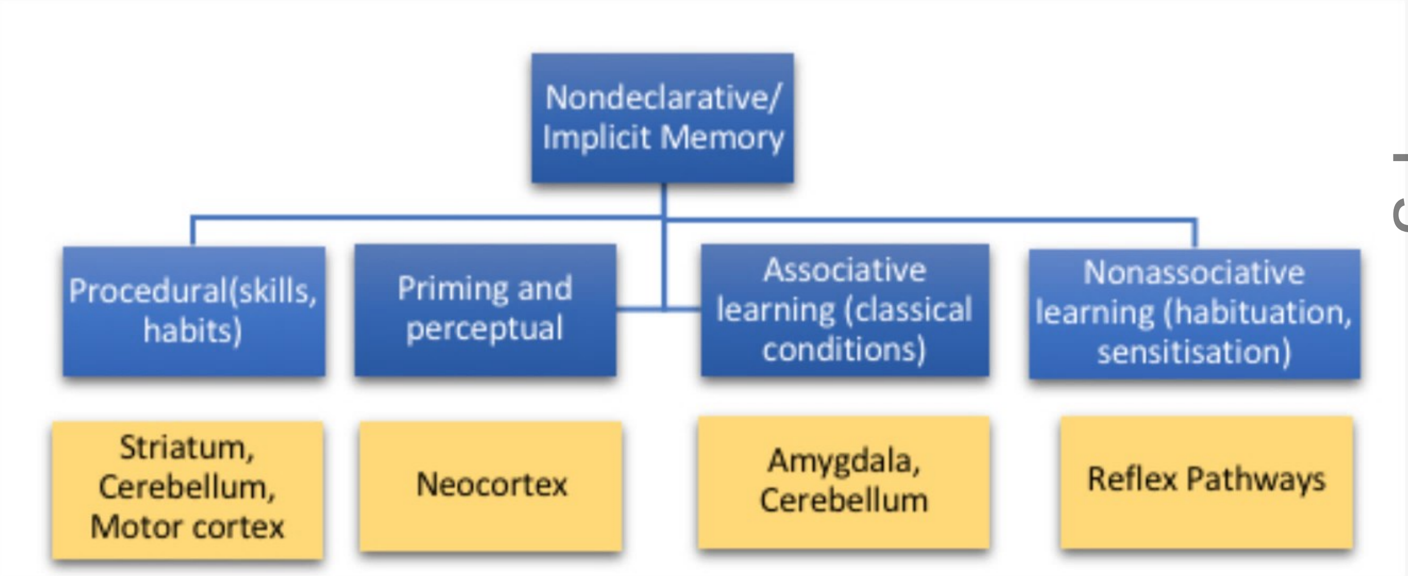
Nondeclarative/ Implicit Memory
Procedural(skills, habits)
Priming and perceptual
Associative learning (classical conditions)
Nonassociative learning (habituation, sensitisation)
Striatum, Cerebellum, Motor cortex
Neocortex
Amygdala, Cerebellum
Reflex Pathways

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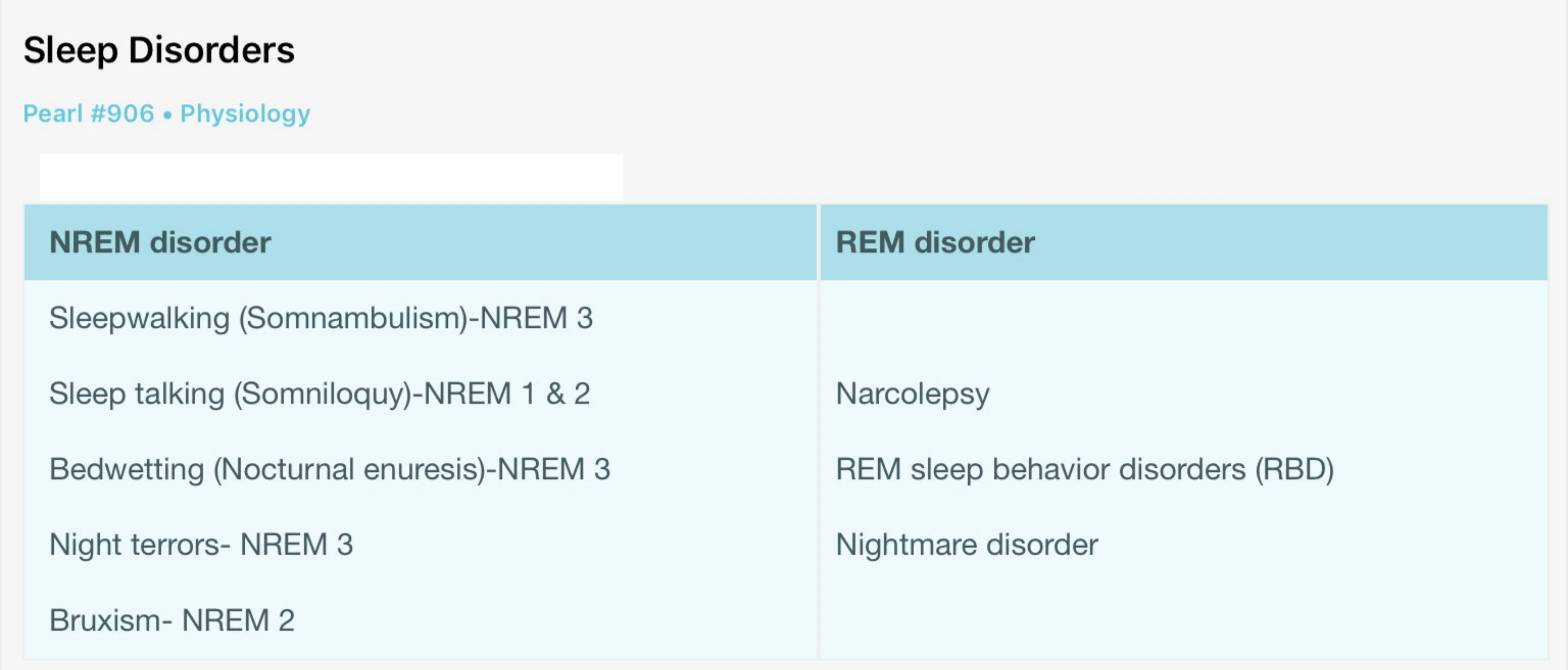
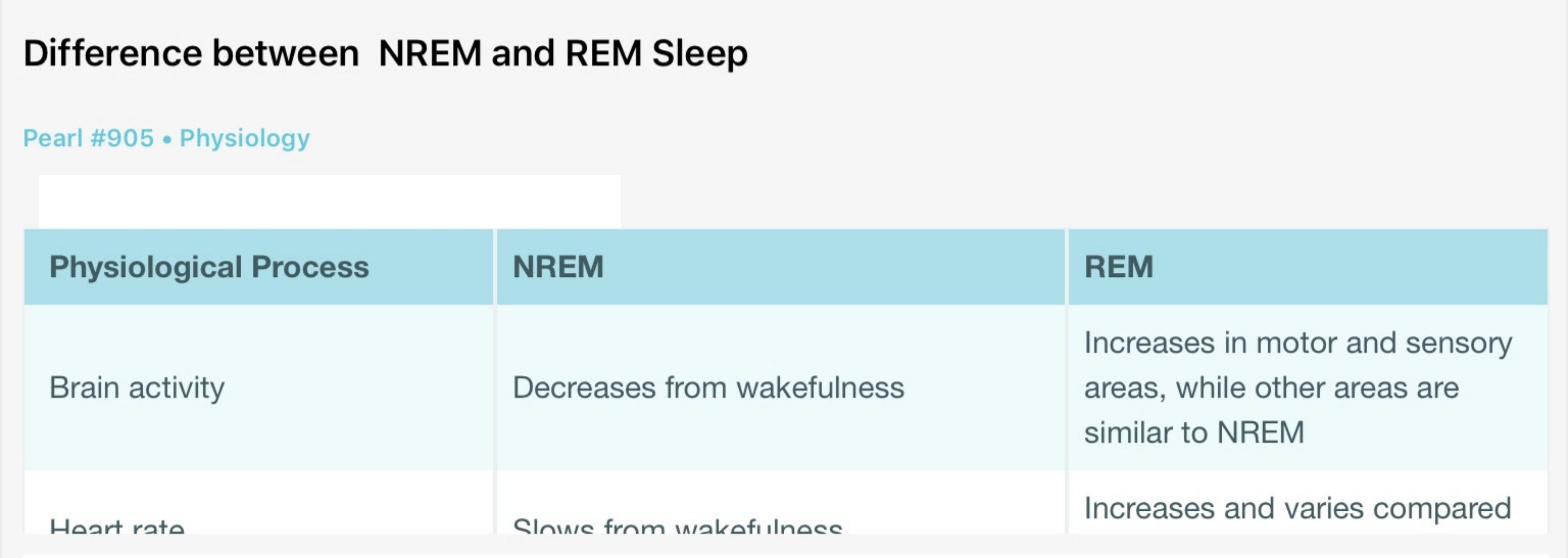


Sleep Disorders

Pearl #906 • Physiology

NREM disorder	REM disorder
Sleepwalking (Somnambulism)-NREM 3	
Sleep talking (Somniloquy)-NREM 1 & 2	Narcolepsy
Bedwetting (Nocturnal enuresis)-NREM 3	REM sleep behavior disorders (RBD)
Night terrors- NREM 3	Nightmare disorder
Bruxism- NREM 2	



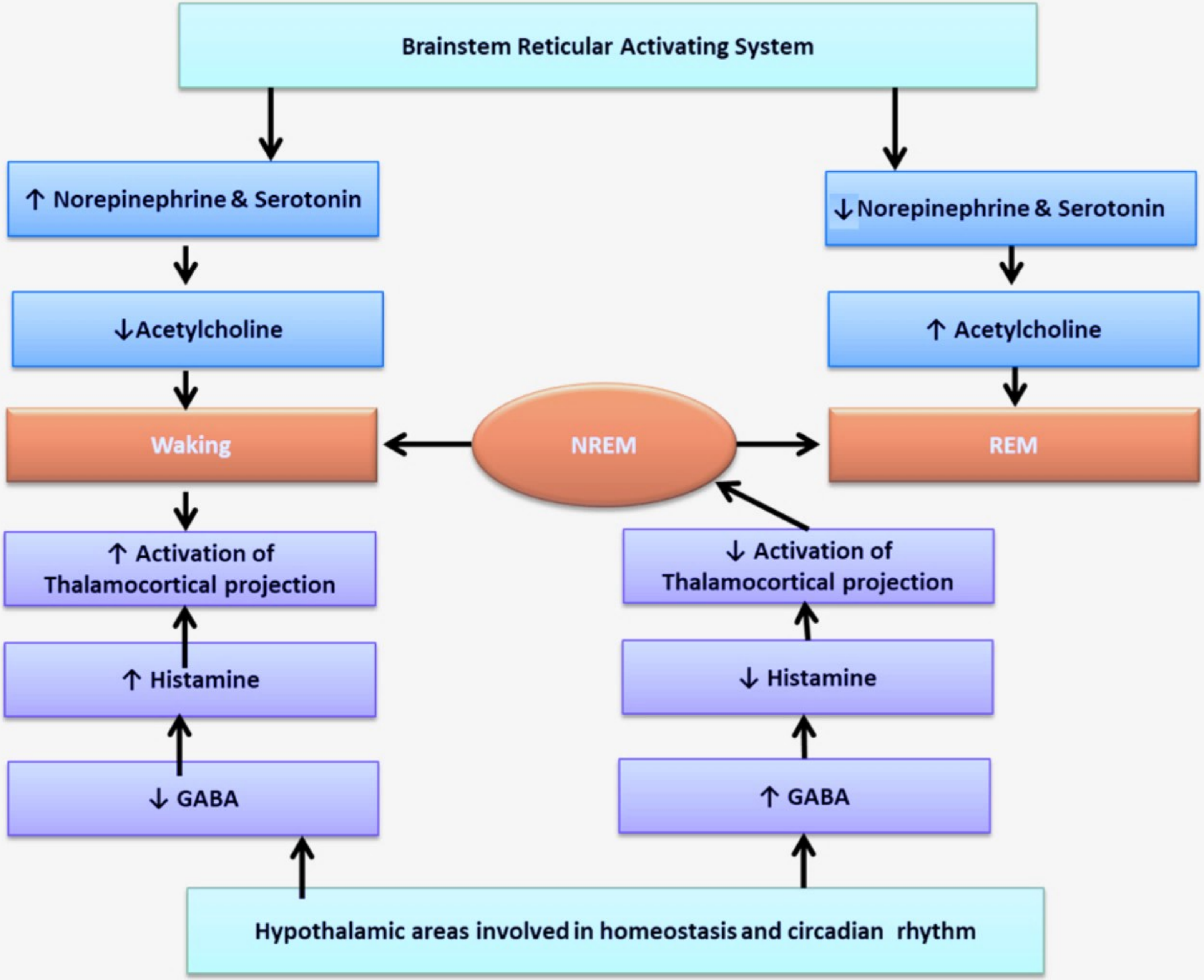
Difference between NREM and REM Sleep

Pearl #905 • Physiology

Physiological Process	NREM	REM
Brain activity	Decreases from wakefulness	Increases in motor and sensory areas, while other areas are similar to NREM
Heart rate	Slows from wakefulness	Increases and varies compared

Neurochemical changes in Sleep-Wake Cycle

Pearl #904 • Physiology


Brainstem Reticular Activating System
↑ Norepinephrine & Serotonin
↓Acetylcholine
Waking
↑ Activation of Thalamocortical projection
↑ Histamine
↓ GABA
NREM
↓Norepinephrine & Serotonin
↑ Acetylcholine
REM
↓ Activation of Thalamocortical projection
↓ Histamine
↑ GABA
Hypothalamic areas involved in homeostasis and circadian rhythm

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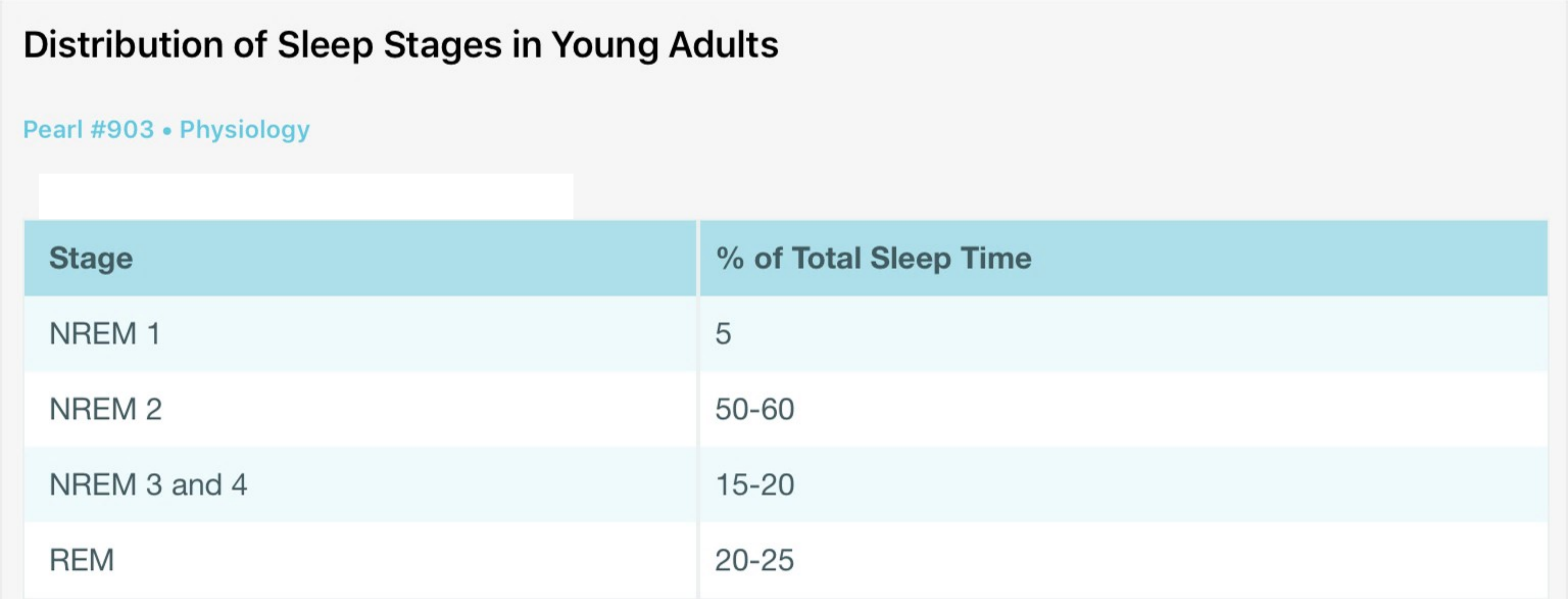


Distribution of Sleep Stages in Young Adults

Pearl #903 • Physiology

Stage	% of Total Sleep Time
NREM 1	5
NREM 2	50-60
NREM 3 and 4	15-20
REM	20-25

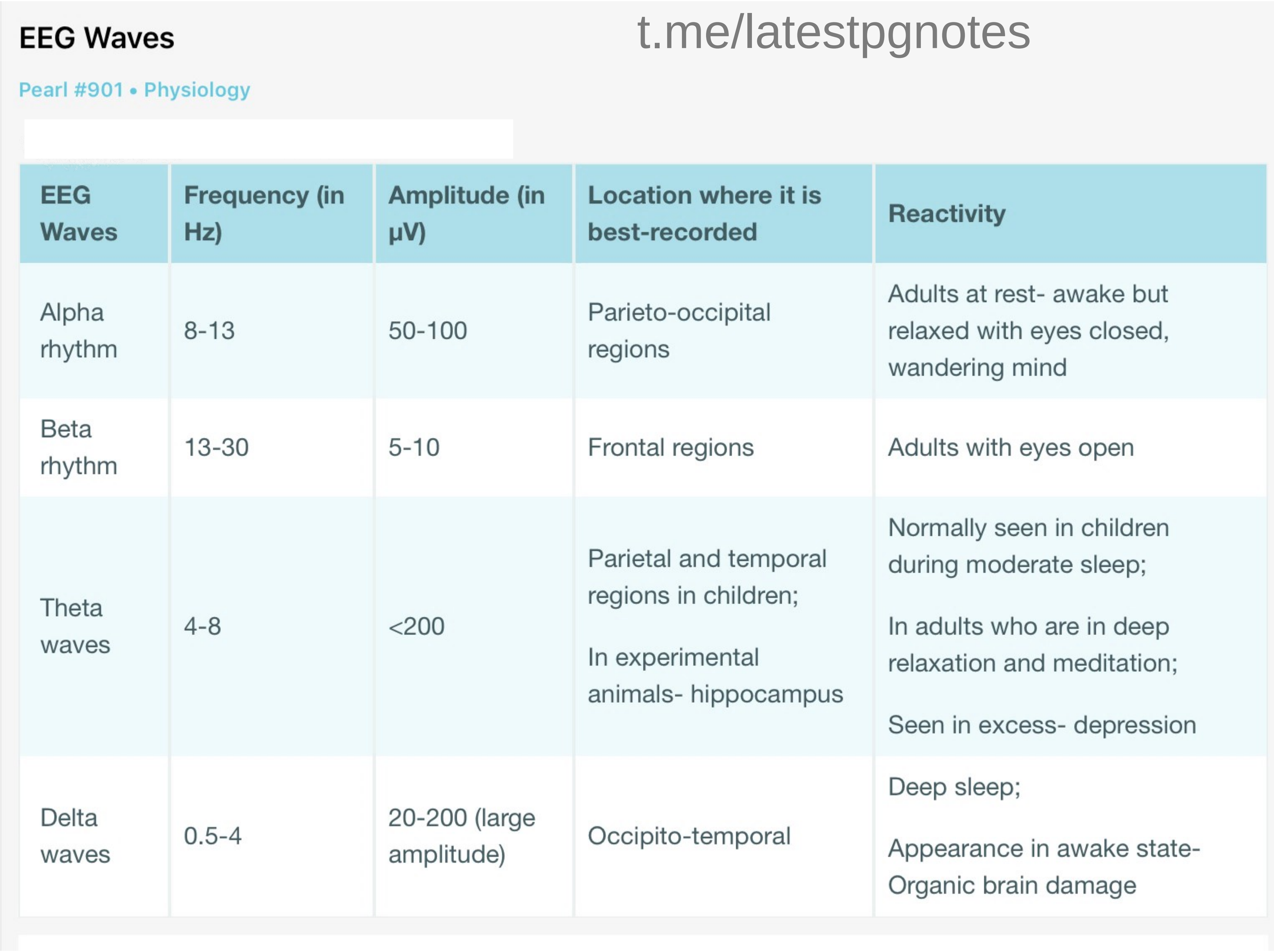
Stages of Arousal and Sleep

Pearl #902 • Physiology

Stage	Behaviour	EEG
Alert wakefulness	Awake, alert with eyes open	**Beta rhythm**(14-30 Hz)
Relaxed wakefulness	Awake, relaxed with eyes closed	***Mainly alpha rhythm** (8–13 Hz) * Changes to the beta rhythm in response to internal or external stimuli.
Relaxed drowsiness	*Fatigued & tired *The head droops,momentary lapses of attention *Sleepy but not asleep	**Decrease in alpha-wave** amplitude and frequency
NREM 1 (N1)	***Light sleep-easily aroused** by moderate stimuli or even by muscle jerks *Continuous lack of awareness	***Mixed frequency waves** (predominantly 2-7 Hz). *Gap in alpha rhythm is filled with theta (4–8 Hz) and delta (slower than 4 Hz) activity ***Vertex waves**

NREM 1 (N1)	***Light sleep-easily aroused** by moderate stimuli or even by muscle jerks *Continuous lack of awareness	***Mixed frequency waves** (predominantly 2-7 Hz). *Gap in alpha rhythm is filled with theta (4–8 Hz) and delta (slower than 4 Hz) activity ***Vertex waves**
NREM 2 (N2)	Further lack of sensitivity to activation and arousal	**Predominant theta activity** (4-7 Hz) **K-complex and sleep spindles** occur periodically
NREM 3 and 4 (N3)	***Deep sleep** *Arousal only with vigorous stimuli **sleep-arousal most difficult**	***Delta>theta activity**
REM (paradoxical) sleep	*50–90 min after sleep onset, episodes repeated every 60–90 min, each episode lasting about 10 min ***dreaming occurs, rapid eye movements,** increase in brain O_2 consumption	*EEG resembles that of alert awake state. ***Saw tooth waves**

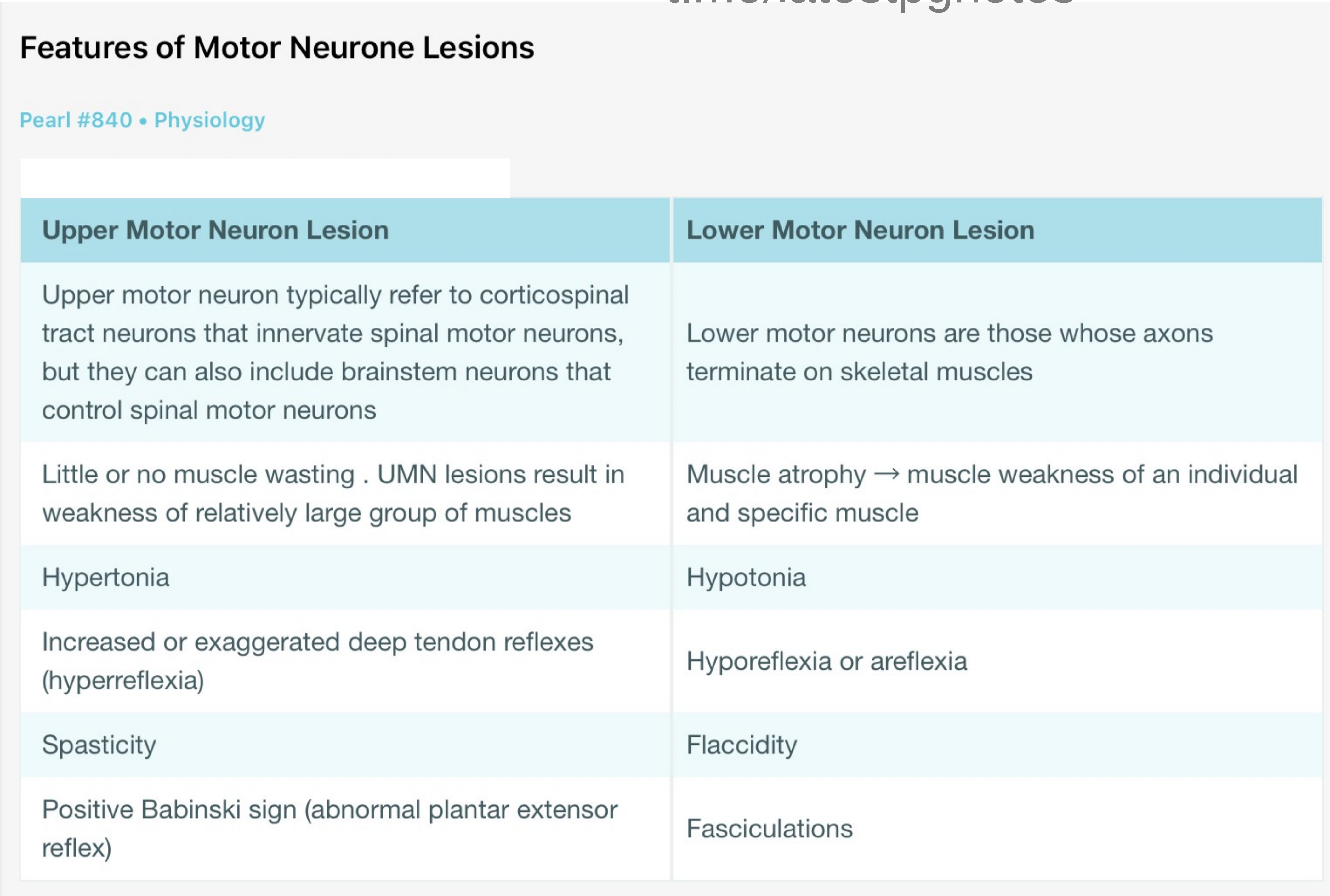
Note- According to new classification Stage 3 and 4 of NREM are grouped together as N3. So as per recent staging NREM has 3 stages (N1, N2, N3)



EEG Waves

Pearl #901 • Physiology

EEG Waves	Frequency (in Hz)	Amplitude (in µV)	Location where it is best-recorded	Reactivity
Alpha rhythm	8-13	50-100	Parieto-occipital regions	Adults at rest- awake but relaxed with eyes closed, wandering mind
Beta rhythm	13-30	5-10	Frontal regions	Adults with eyes open
Theta waves	4-8	<200	Parietal and temporal regions in children; In experimental animals- hippocampus	Normally seen in children during moderate sleep; In adults who are in deep relaxation and meditation; Seen in excess- depression
Delta waves	0.5-4	20-200 (large amplitude)	Occipito-temporal	Deep sleep; Appearance in awake state- Organic brain damage



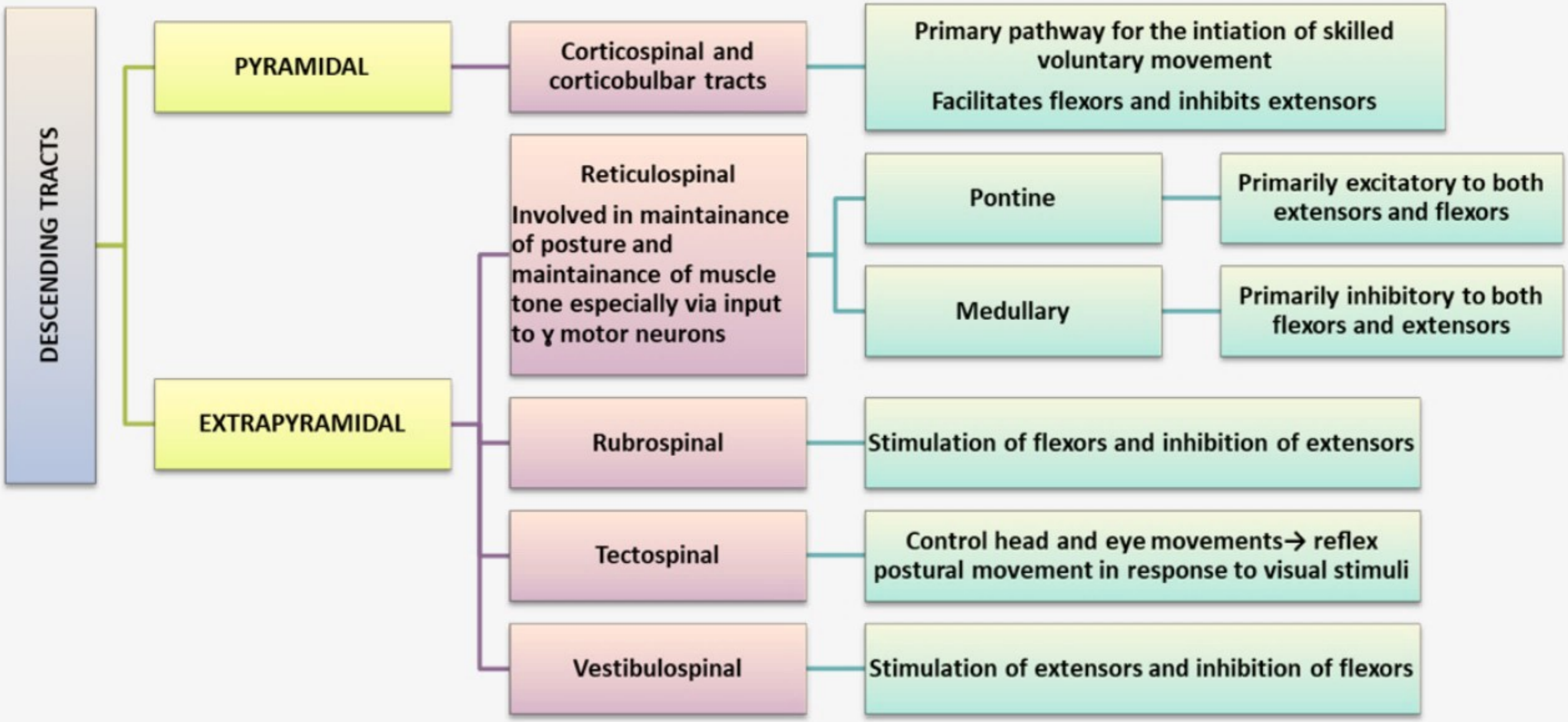
Features of Motor Neurone Lesions

Pearl #840 • Physiology

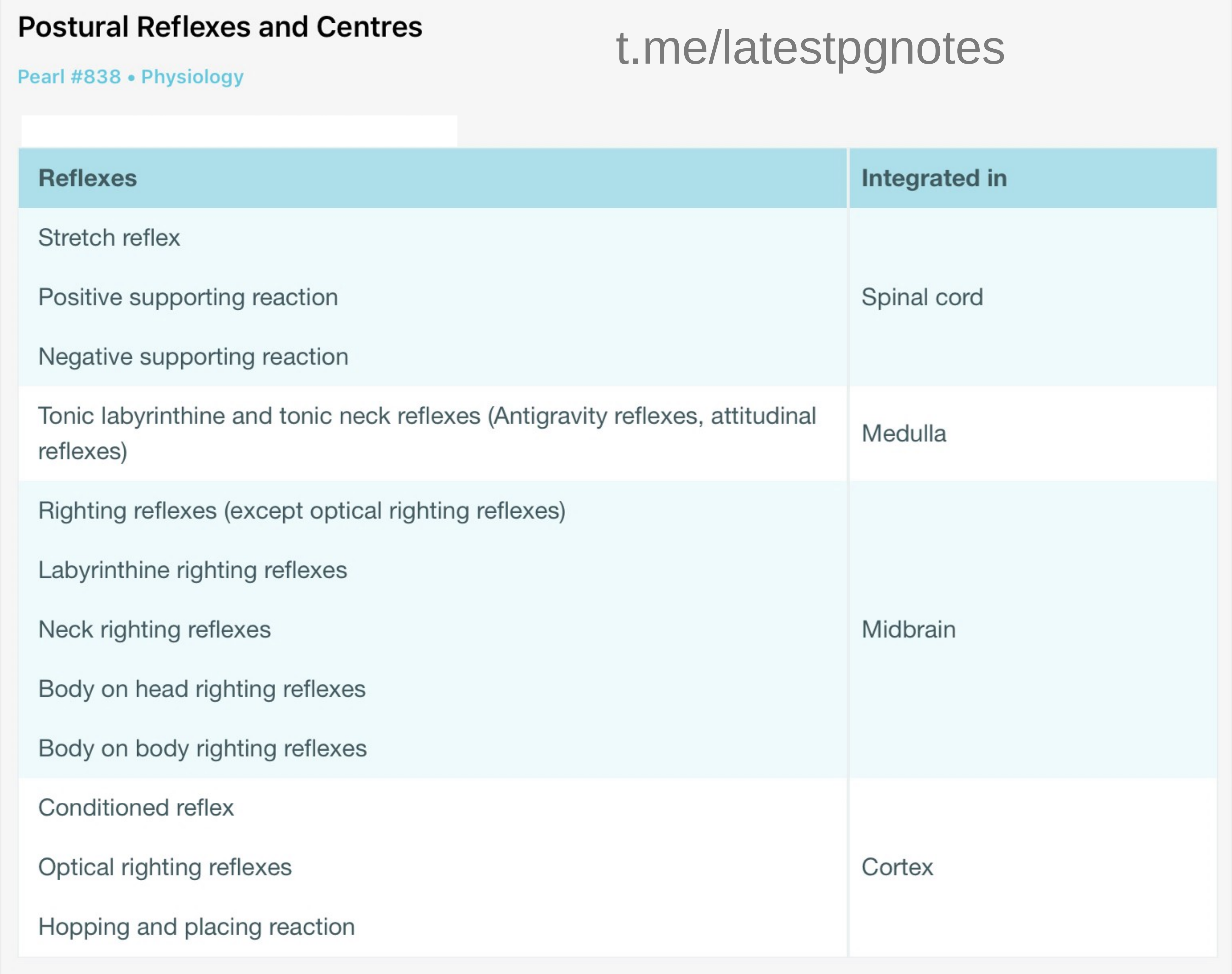
Upper Motor Neuron Lesion	Lower Motor Neuron Lesion
Upper motor neuron typically refer to corticospinal tract neurons that innervate spinal motor neurons, but they can also include brainstem neurons that control spinal motor neurons	Lower motor neurons are those whose axons terminate on skeletal muscles
Little or no muscle wasting . UMN lesions result in weakness of relatively large group of muscles	Muscle atrophy → muscle weakness of an individual and specific muscle
Hypertonia	Hypotonia
Increased or exaggerated deep tendon reflexes (hyperreflexia)	Hyporeflexia or areflexia
Spasticity	Flaccidity
Positive Babinski sign (abnormal plantar extensor reflex)	Fasciculations

Descending Pathways

Pearl #839 • Physiology



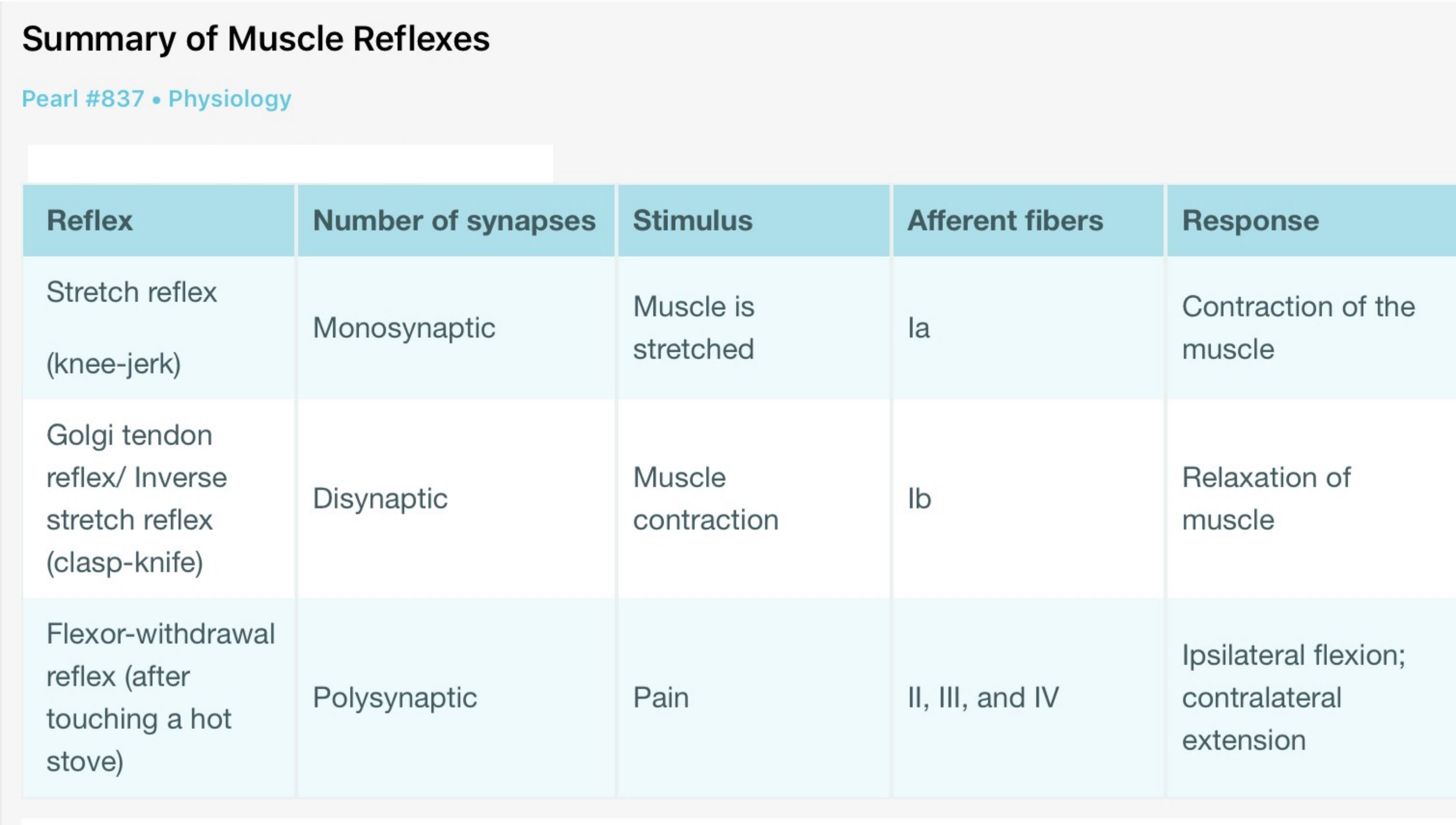
- DESCENDING TRACTS
  - PYRAMIDAL
    - Corticospinal and corticobulbar tracts
      - Primary pathway for the intiation of skilled voluntary movement
      - Facilitates flexors and inhibits extensors
  - EXTRAPYRAMIDAL
    - Reticulospinal: Involved in maintainance of posture and maintainance of muscle tone especially via input to ɣ motor neurons
      - Pontine
        - Primarily excitatory to both extensors and flexors
      - Medullary
        - Primarily inhibitory to both flexors and extensors
    - Rubrospinal
      - Stimulation of flexors and inhibition of extensors
    - Tectospinal
      - Control head and eye movements→ reflex postural movement in response to visual stimuli
    - Vestibulospinal
      - Stimulation of extensors and inhibition of flexors



Postural Reflexes and Centres

Pearl #838 • Physiology

Reflexes	Integrated in
Stretch reflex Positive supporting reaction Negative supporting reaction	Spinal cord
Tonic labyrinthine and tonic neck reflexes (Antigravity reflexes, attitudinal reflexes)	Medulla
Righting reflexes (except optical righting reflexes) Labyrinthine righting reflexes Neck righting reflexes Body on head righting reflexes Body on body righting reflexes	Midbrain
Conditioned reflex Optical righting reflexes Hopping and placing reaction	Cortex



Summary of Muscle Reflexes

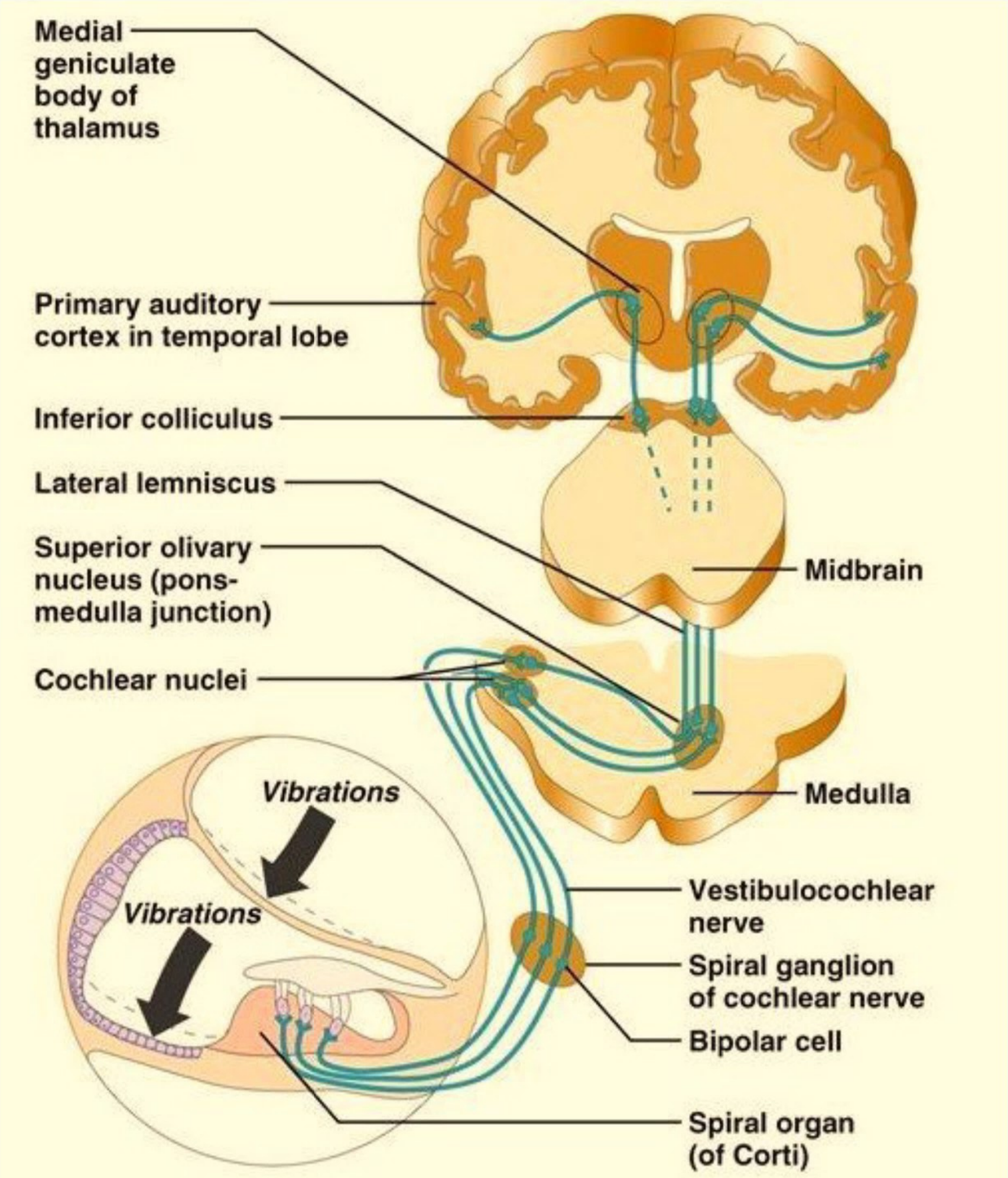
Pearl #837 • Physiology

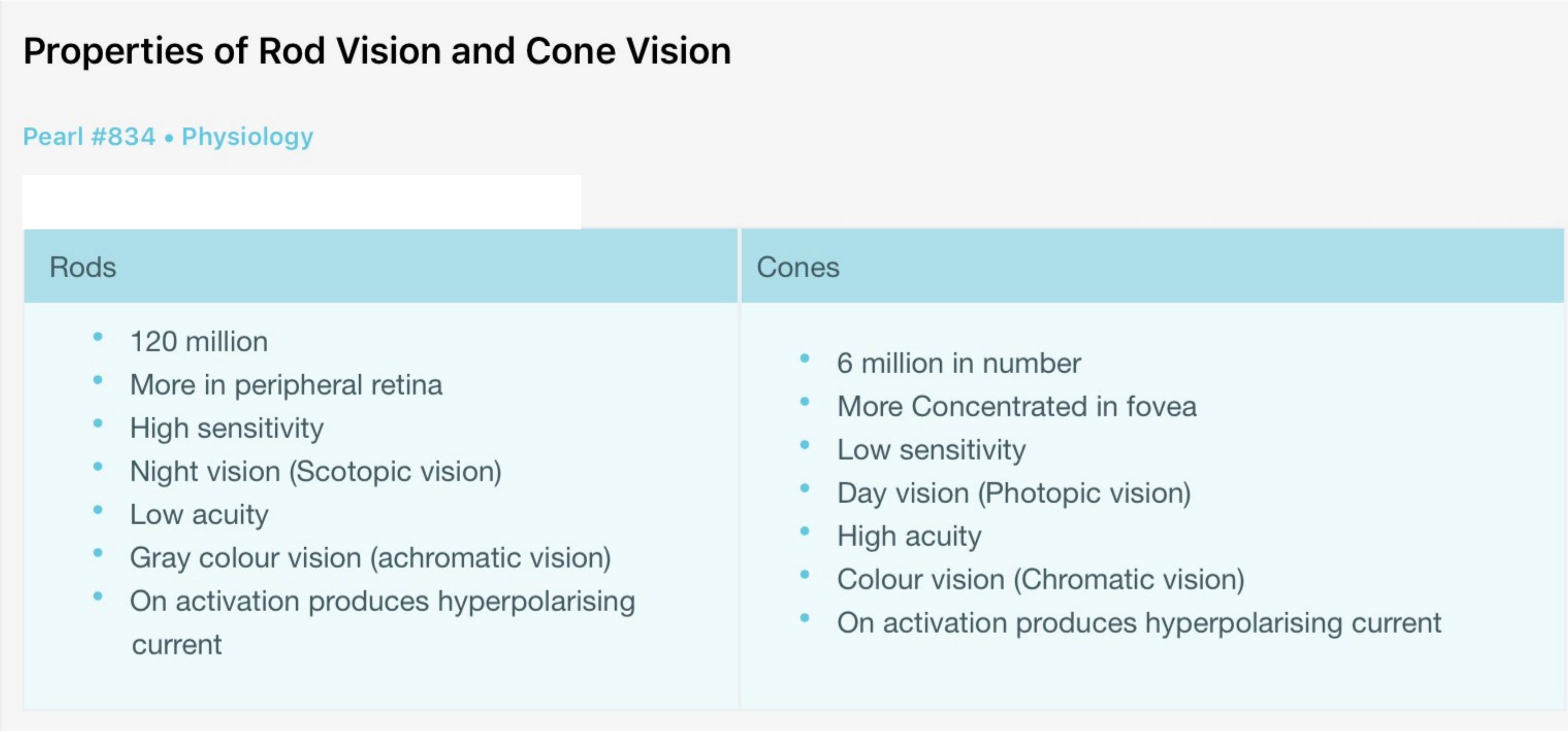
Reflex	Number of synapses	Stimulus	Afferent fibers	Response
Stretch reflex (knee-jerk)	Monosynaptic	Muscle is stretched	Ia	Contraction of the muscle
Golgi tendon reflex/ Inverse stretch reflex (clasp-knife)	Disynaptic	Muscle contraction	Ib	Relaxation of muscle
Flexor-withdrawal reflex (after touching a hot stove)	Polysynaptic	Pain	II, III, and IV	Ipsilateral flexion; contralateral extension

Central Auditory Pathway

Pearl #836 • Physiology

Mneumonic- E. coli MA (refer flow chart).

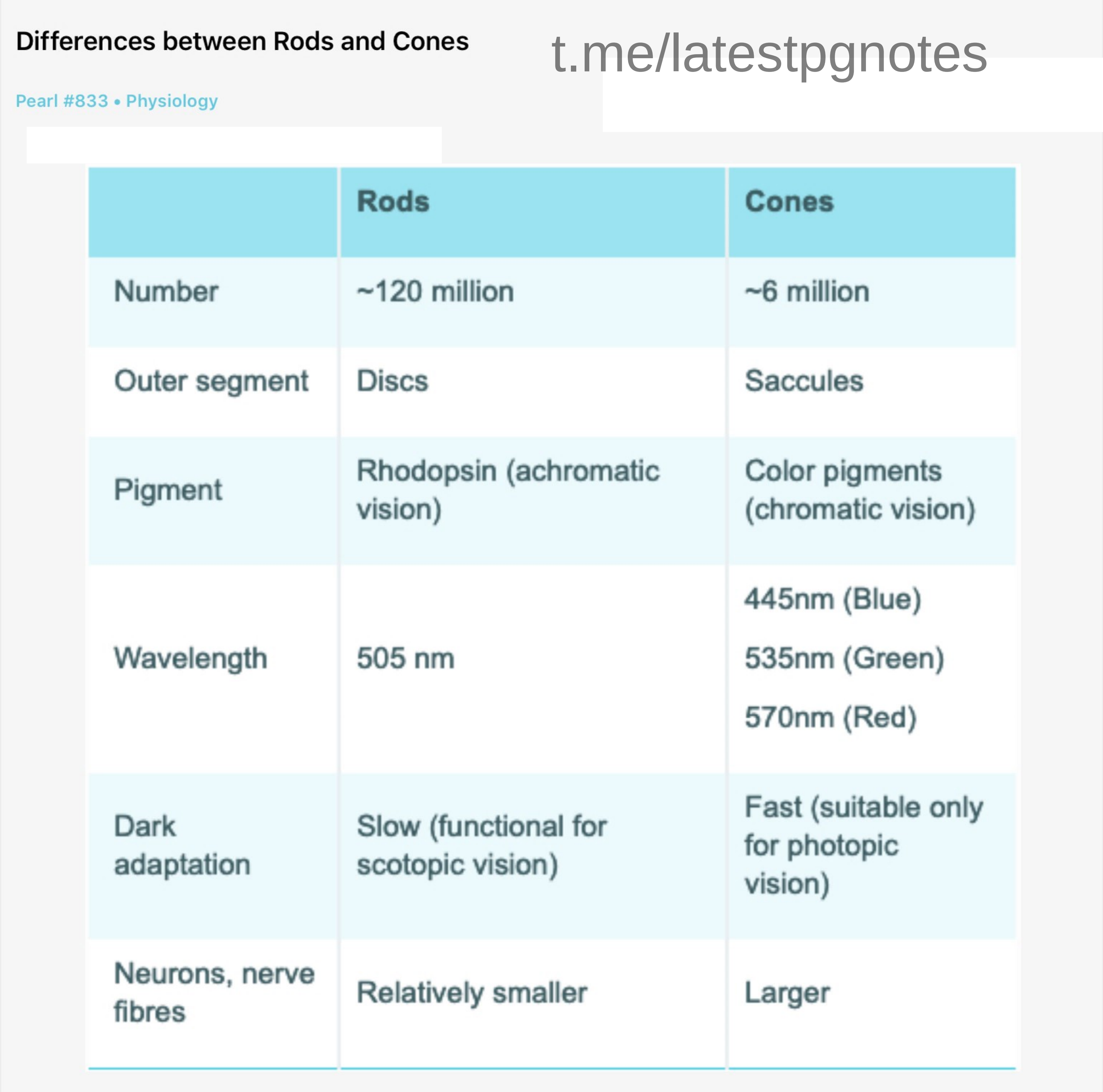

Medial geniculate body of thalamus
Primary auditory cortex in temporal lobe
Inferior colliculus
Lateral lemniscus
Superior olivary nucleus (pons-medulla junction)
Cochlear nuclei
Midbrain
Medulla
Vibrations
Vibrations
Vestibulocochlear nerve
Spiral ganglion of cochlear nerve
Bipolar cell
Spiral organ (of Corti)



Properties of Rod Vision and Cone Vision

Pearl #834 • Physiology

Rods	Cones
120 million	6 million in number
More in peripheral retina	More Concentrated in fovea
High sensitivity	Low sensitivity
Night vision (Scotopic vision)	Day vision (Photopic vision)
Low acuity	High acuity
Gray colour vision (achromatic vision)	Colour vision (Chromatic vision)
On activation produces hyperpolarising current	On activation produces hyperpolarising current



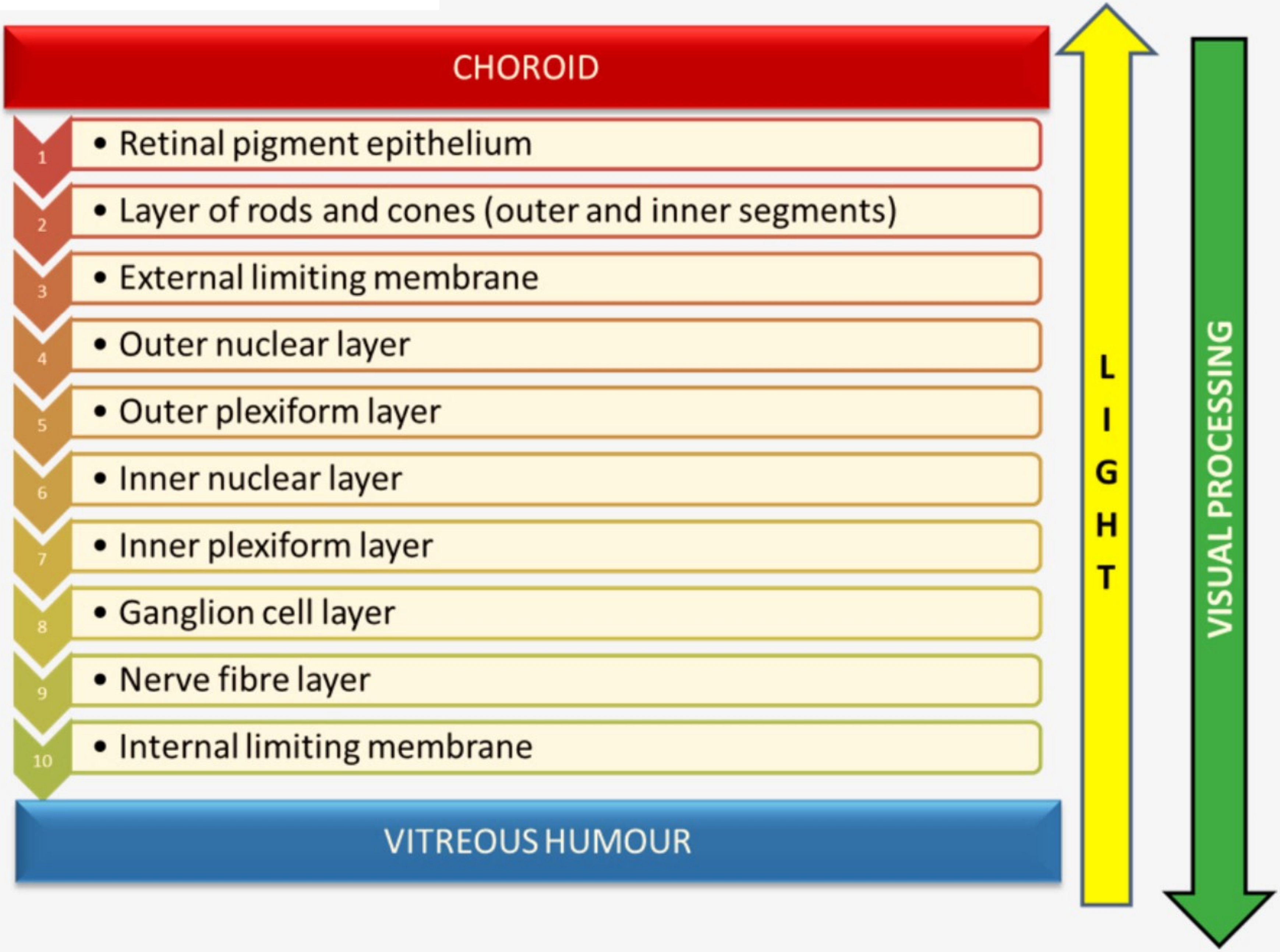
Differences between Rods and Cones

Pearl #833 • Physiology

	Rods	Cones
Number	~120 million	~6 million
Outer segment	Discs	Saccules
Pigment	Rhodopsin (achromatic vision)	Color pigments (chromatic vision)
Wavelength	505 nm	445nm (Blue) 535nm (Green) 570nm (Red)
Dark adaptation	Slow (functional for scotopic vision)	Fast (suitable only for photopic vision)
Neurons, nerve fibres	Relatively smaller	Larger

Layers of Retina

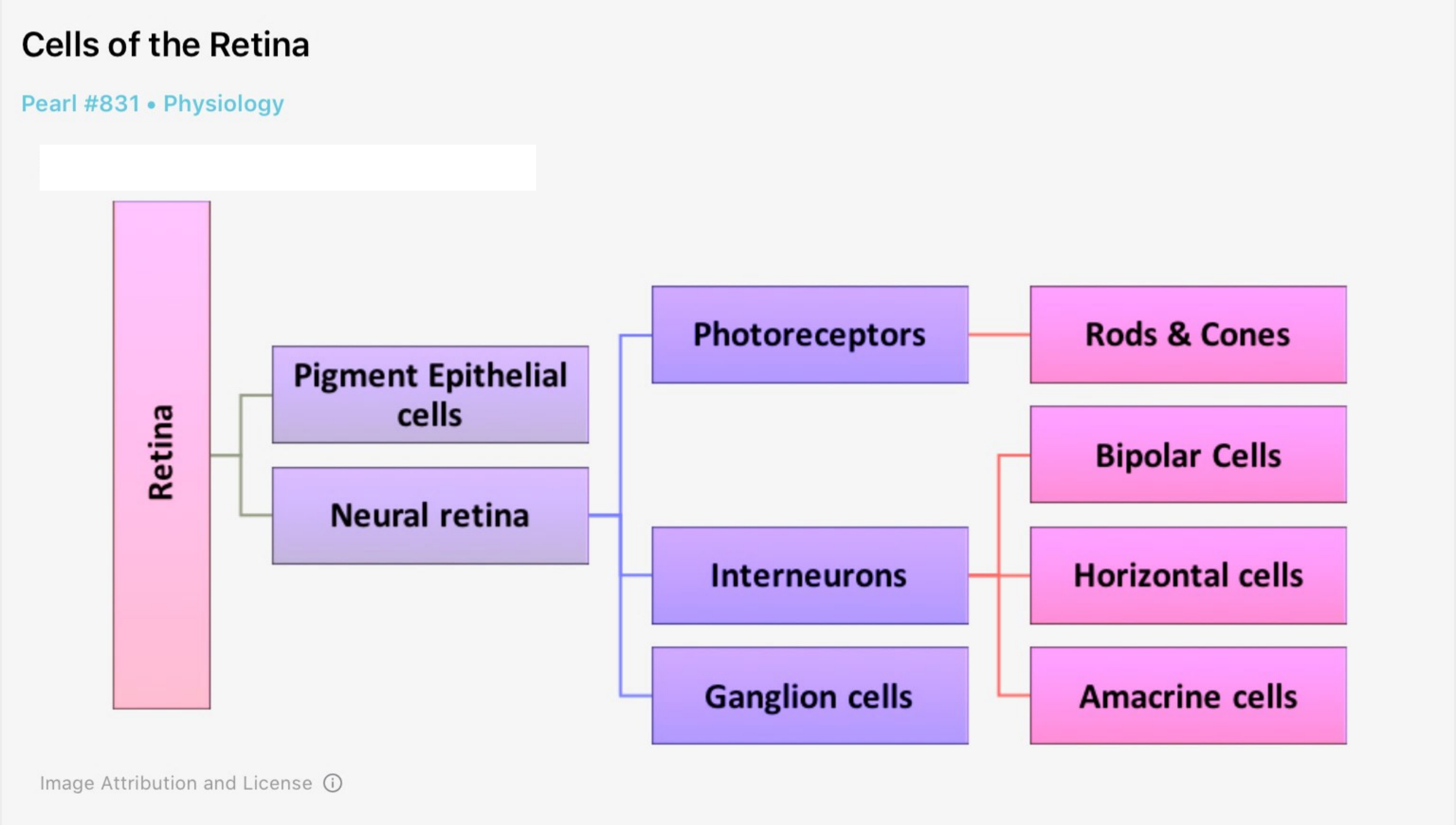
Pearl #832 • Physiology



CHOROID

1. Retinal pigment epithelium
2. Layer of rods and cones (outer and inner segments)
3. External limiting membrane
4. Outer nuclear layer
5. Outer plexiform layer
6. Inner nuclear layer
7. Inner plexiform layer
8. Ganglion cell layer
9. Nerve fibre layer
10. Internal limiting membrane

VITREOUS HUMOUR



Cells of the Retina

Pearl #831 • Physiology

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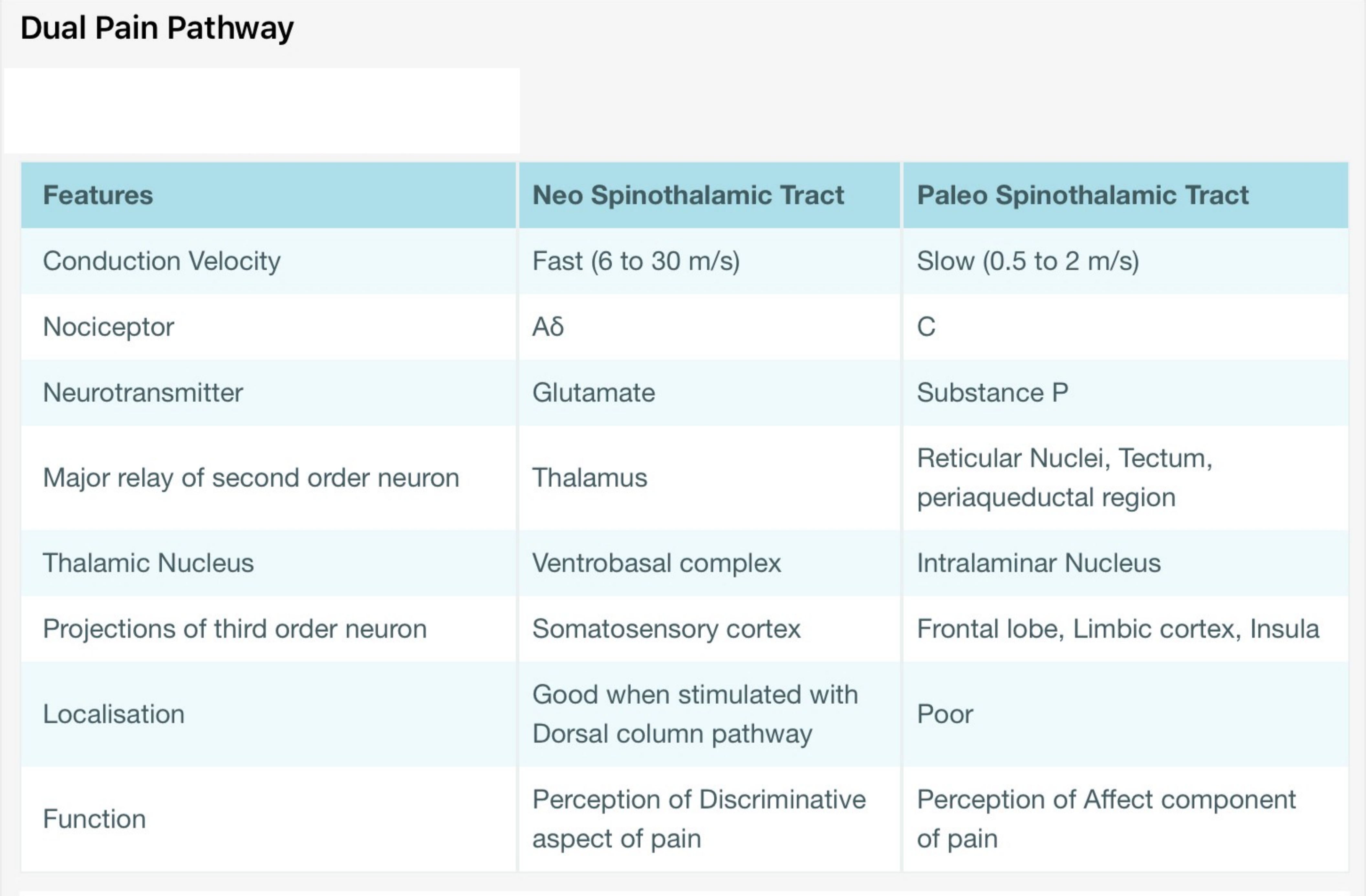
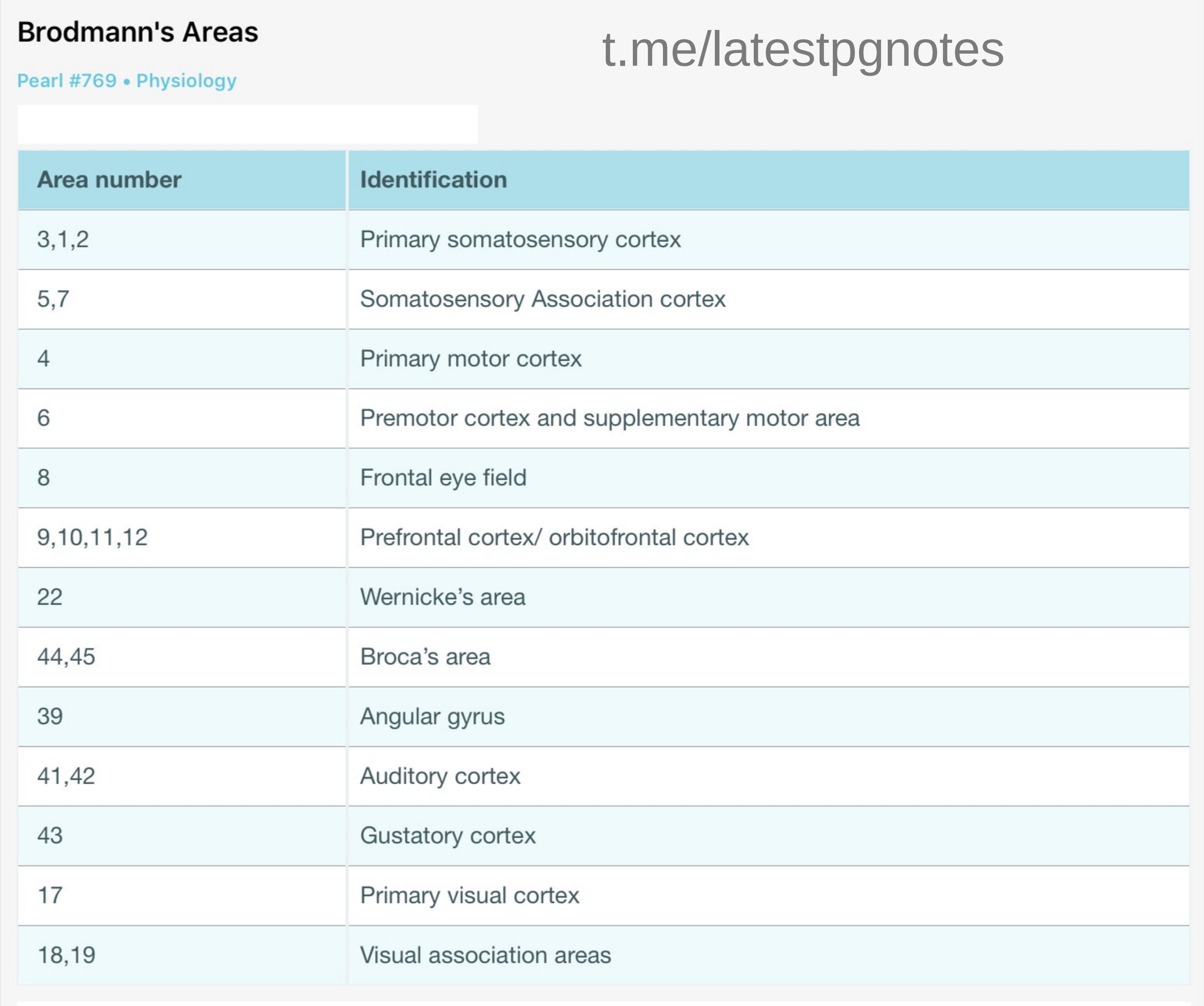


Dual Pain Pathway

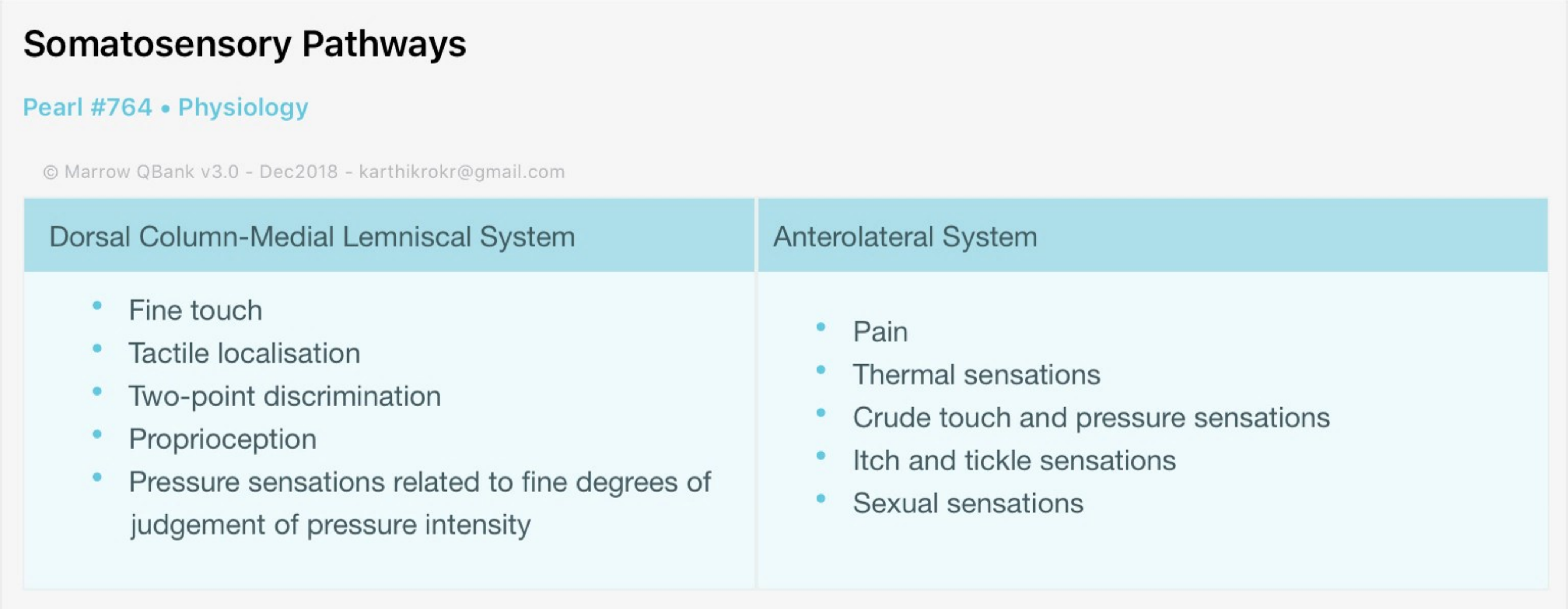
Features	Neo Spinothalamic Tract	Paleo Spinothalamic Tract
Conduction Velocity	Fast (6 to 30 m/s)	Slow (0.5 to 2 m/s)
Nociceptor	Aδ	C
Neurotransmitter	Glutamate	Substance P
Major relay of second order neuron	Thalamus	Reticular Nuclei, Tectum, periaqueductal region
Thalamic Nucleus	Ventrobasal complex	Intralaminar Nucleus
Projections of third order neuron	Somatosensory cortex	Frontal lobe, Limbic cortex, Insula
Localisation	Good when stimulated with Dorsal column pathway	Poor
Function	Perception of Discriminative aspect of pain	Perception of Affect component of pain



Brodmann's Areas

Pearl #769 • Physiology

Area number	Identification
3,1,2	Primary somatosensory cortex
5,7	Somatosensory Association cortex
4	Primary motor cortex
6	Premotor cortex and supplementary motor area
8	Frontal eye field
9,10,11,12	Prefrontal cortex/ orbitofrontal cortex
22	Wernicke’s area
44,45	Broca’s area
39	Angular gyrus
41,42	Auditory cortex
43	Gustatory cortex
17	Primary visual cortex
18,19	Visual association areas



Somatosensory Pathways

Pearl #764 • Physiology

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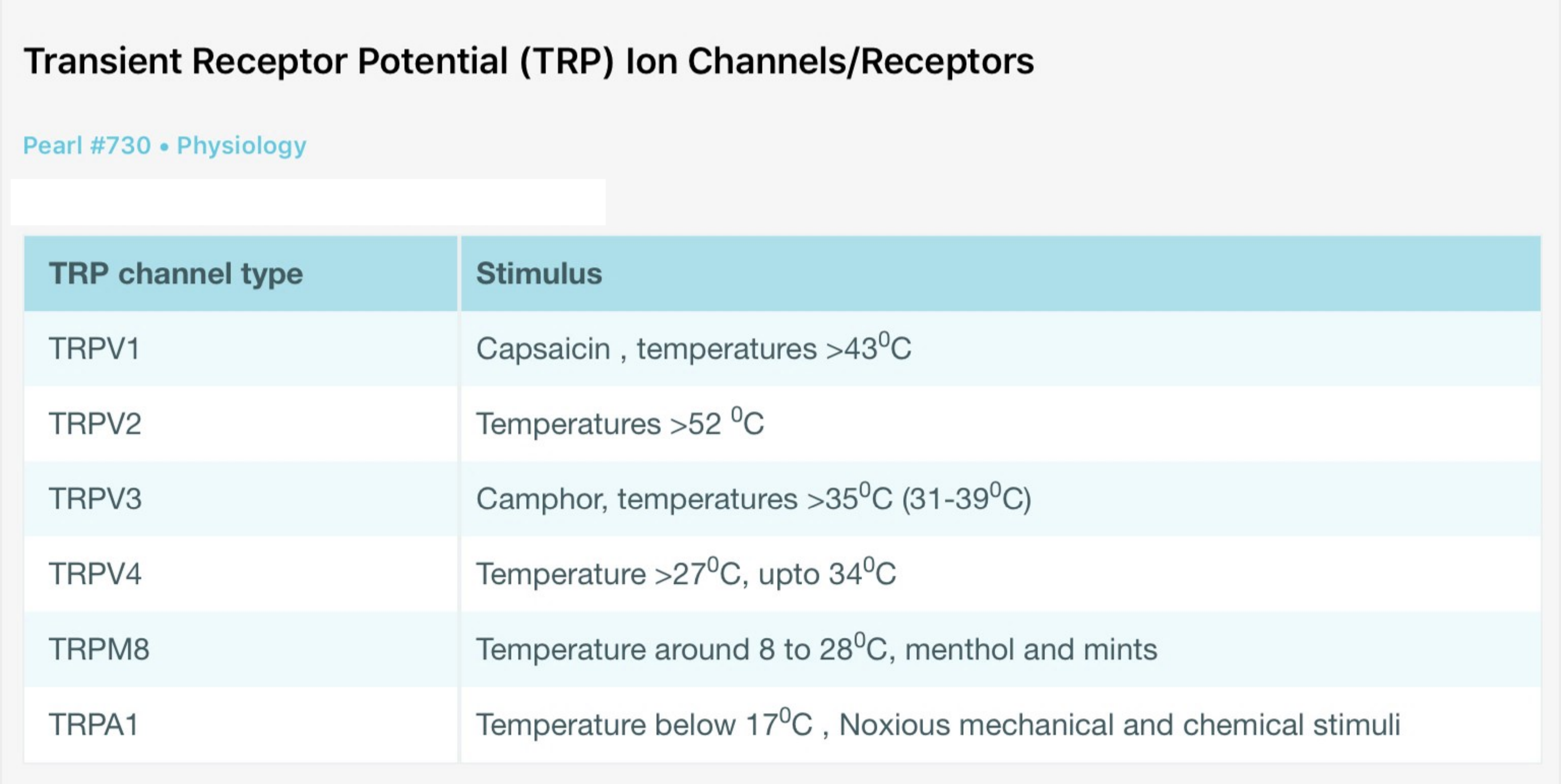
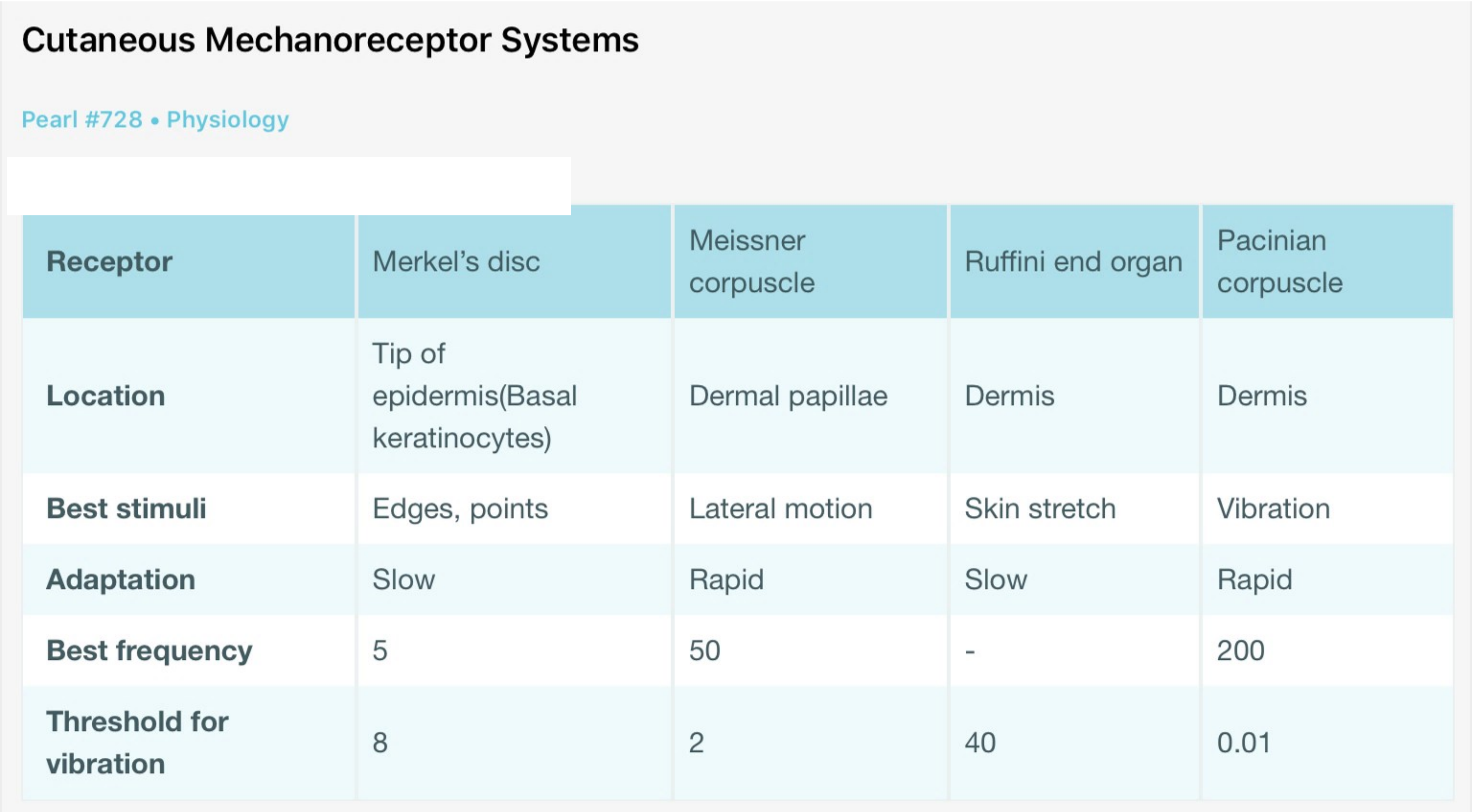
Dorsal Column-Medial Lemniscal System	Anterolateral System
• Fine touch • Tactile localisation • Two-point discrimination • Proprioception • Pressure sensations related to fine degrees of judgement of pressure intensity	• Pain • Thermal sensations • Crude touch and pressure sensations • Itch and tickle sensations • Sexual sensations



Transient Receptor Potential (TRP) Ion Channels/Receptors

Pearl #730 • Physiology

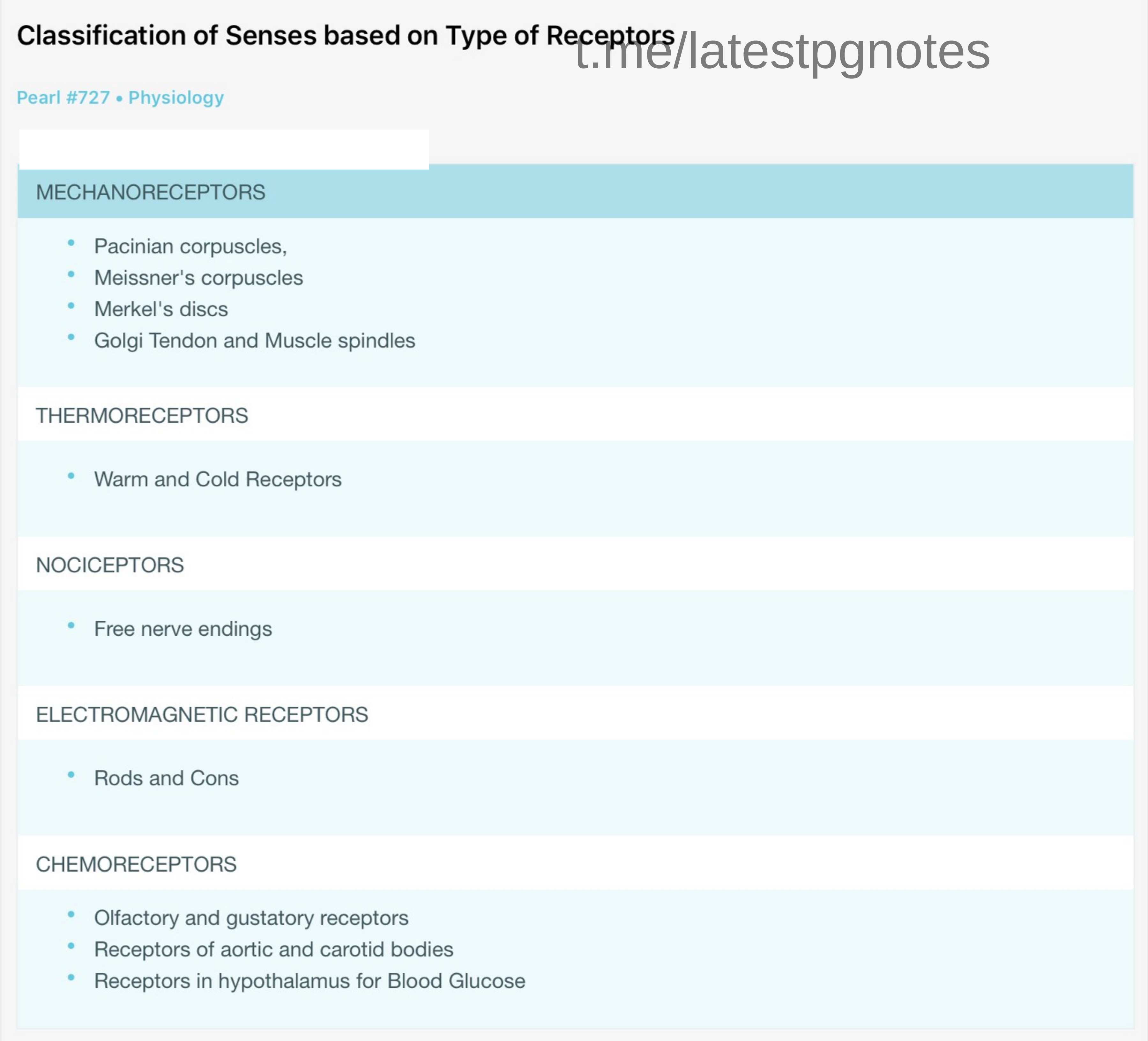
TRP channel type	Stimulus
TRPV1	Capsaicin , temperatures >43^{0}C
TRPV2	Temperatures >52 ^{0}C
TRPV3	Camphor, temperatures >35^{0}C (31-39^{0}C)
TRPV4	Temperature >27^{0}C, upto 34^{0}C
TRPM8	Temperature around 8 to 28^{0}C, menthol and mints
TRPA1	Temperature below 17^{0}C , Noxious mechanical and chemical stimuli



Cutaneous Mechanoreceptor Systems

Pearl #728 • Physiology

Receptor	Merkel's disc	Meissner corpuscle	Ruffini end organ	Pacinian corpuscle
Location	Tip of epidermis(Basal keratinocytes)	Dermal papillae	Dermis	Dermis
Best stimuli	Edges, points	Lateral motion	Skin stretch	Vibration
Adaptation	Slow	Rapid	Slow	Rapid
Best frequency	5	50	-	200
Threshold for vibration	8	2	40	0.01



Classification of Senses based on Type of Receptors

Pearl #727 • Physiology

MECHANORECEPTORS

- Pacinian corpuscles,
- Meissner's corpuscles
- Merkel's discs
- Golgi Tendon and Muscle spindles

THERMORECEPTORS

- Warm and Cold Receptors

NOCICEPTORS

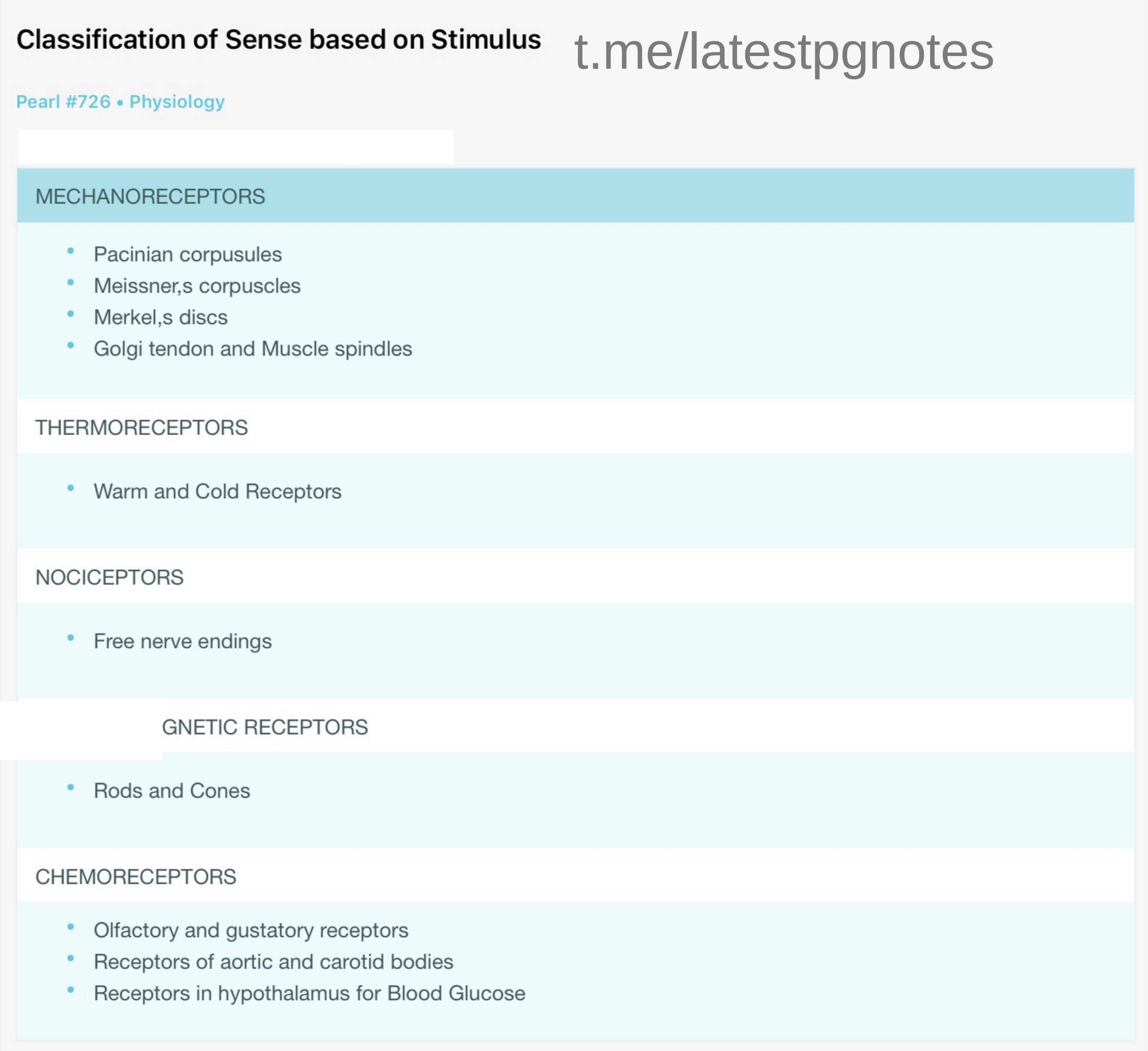
- Free nerve endings

ELECTROMAGNETIC RECEPTORS

- Rods and Cons

CHEMORECEPTORS

- Olfactory and gustatory receptors
- Receptors of aortic and carotid bodies
- Receptors in hypothalamus for Blood Glucose



Classification of Sense based on Stimulus

Pearl #726 • Physiology

MECHANORECEPTORS

- Pacinian corpusules
- Meissner,s corpuscles
- Merkel,s discs
- Golgi tendon and Muscle spindles

THERMORECEPTORS

- Warm and Cold Receptors

NOCICEPTORS

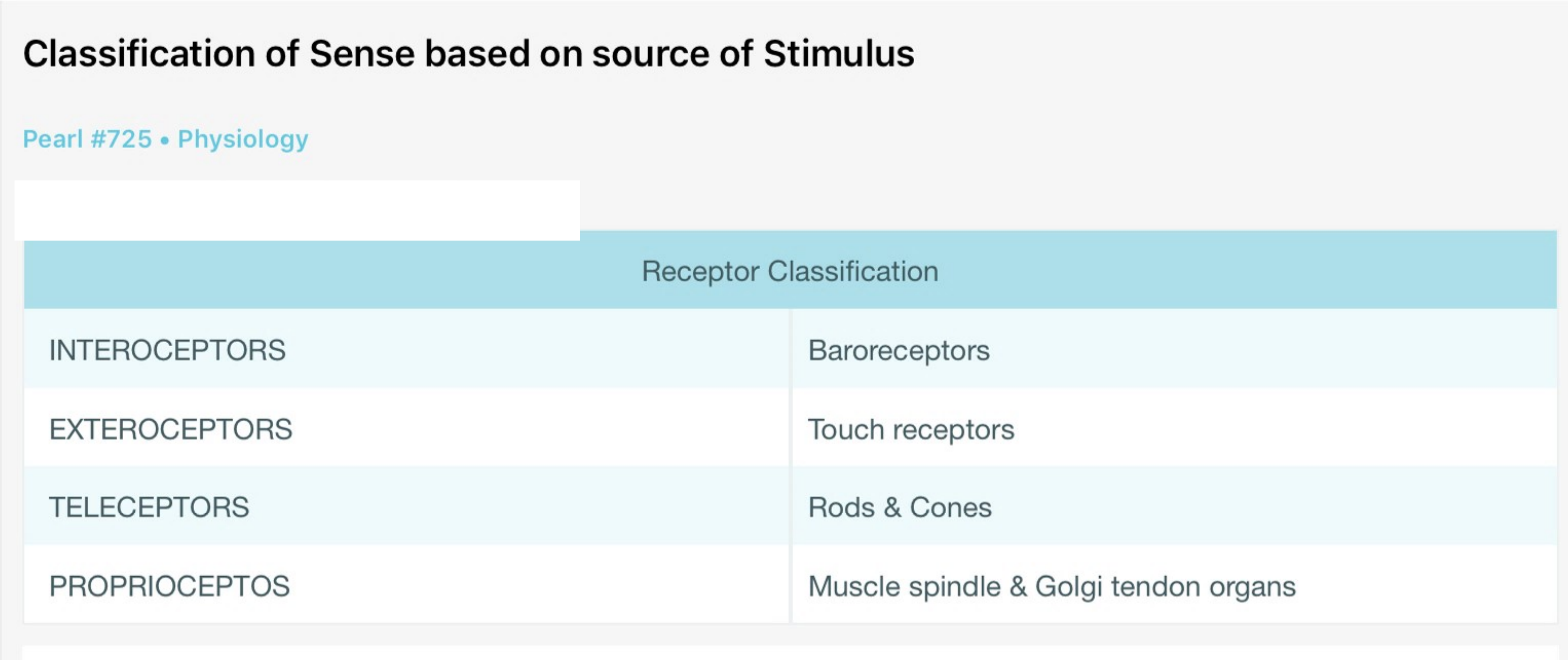
- Free nerve endings

GNETIC RECEPTORS

- Rods and Cones

CHEMORECEPTORS

- Olfactory and gustatory receptors
- Receptors of aortic and carotid bodies
- Receptors in hypothalamus for Blood Glucose



Classification of Sense based on source of Stimulus

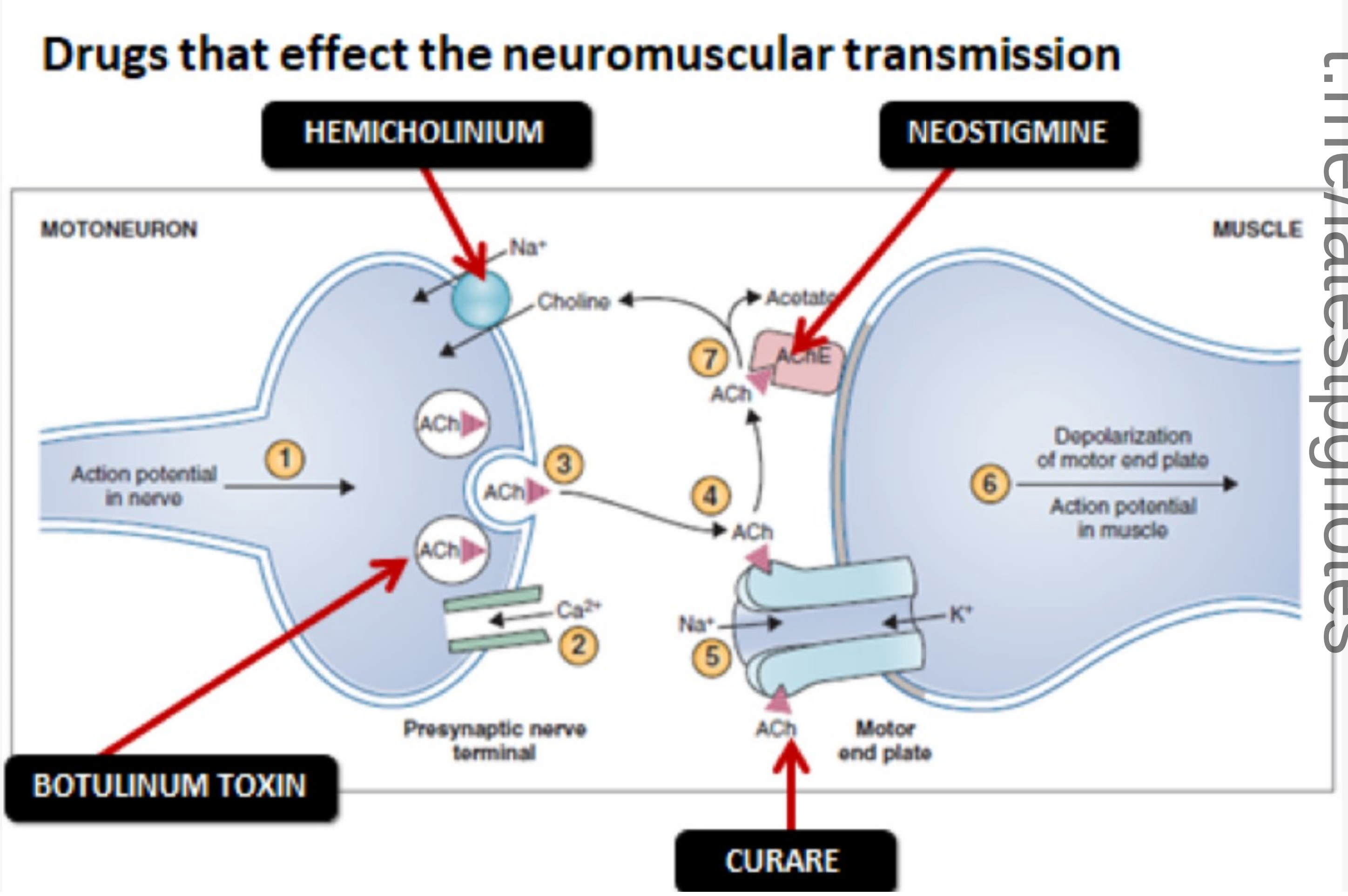
Pearl #725 • Physiology

Receptor Classification	
INTEROCEPTORS	Baroreceptors
EXTEROCEPTORS	Touch receptors
TELECEPTORS	Rods & Cones
PROPRIOCEPTOS	Muscle spindle & Golgi tendon organs

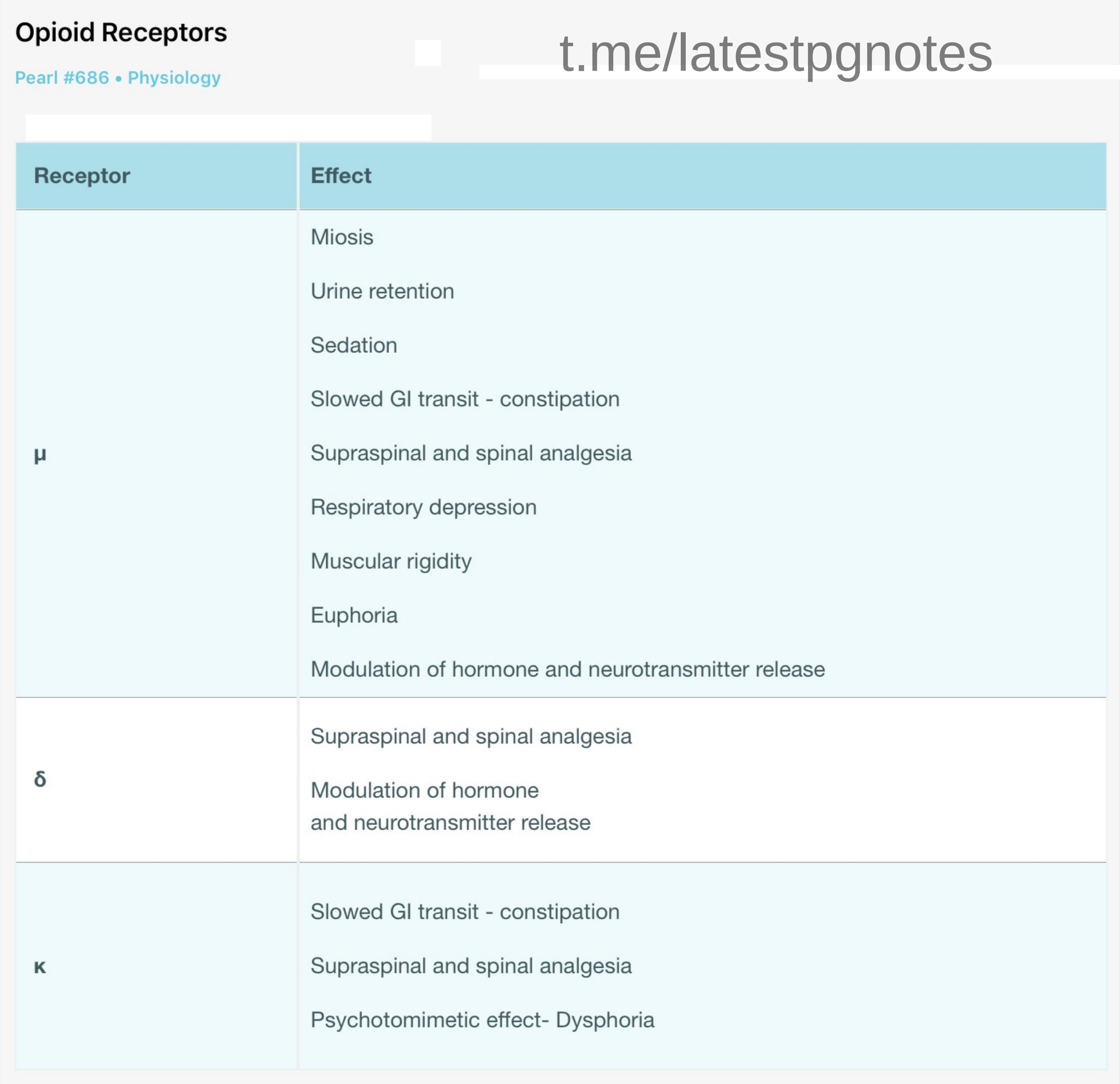
Agents Affecting Neuromuscular Transmission

Pearl #687 • Physiology

Example	Action	Effect on Neuromuscular Transmission
Botulinum toxin	Blocks release of ACh from presynaptic terminal	Total blockade of terminals
Curare	Competes with ACh for receptors on motor end plate	Decreases size of EPP; maximal doses produce end plate paralysis of respiratory muscles and death
Neostigmine	Inhibits acetylcholinesterase	Prolongs and enhances action of ACh at muscle end plate
Hemicholinium	Blocks reuptake of choline	Depletes ACh stores from presynaptic terminal



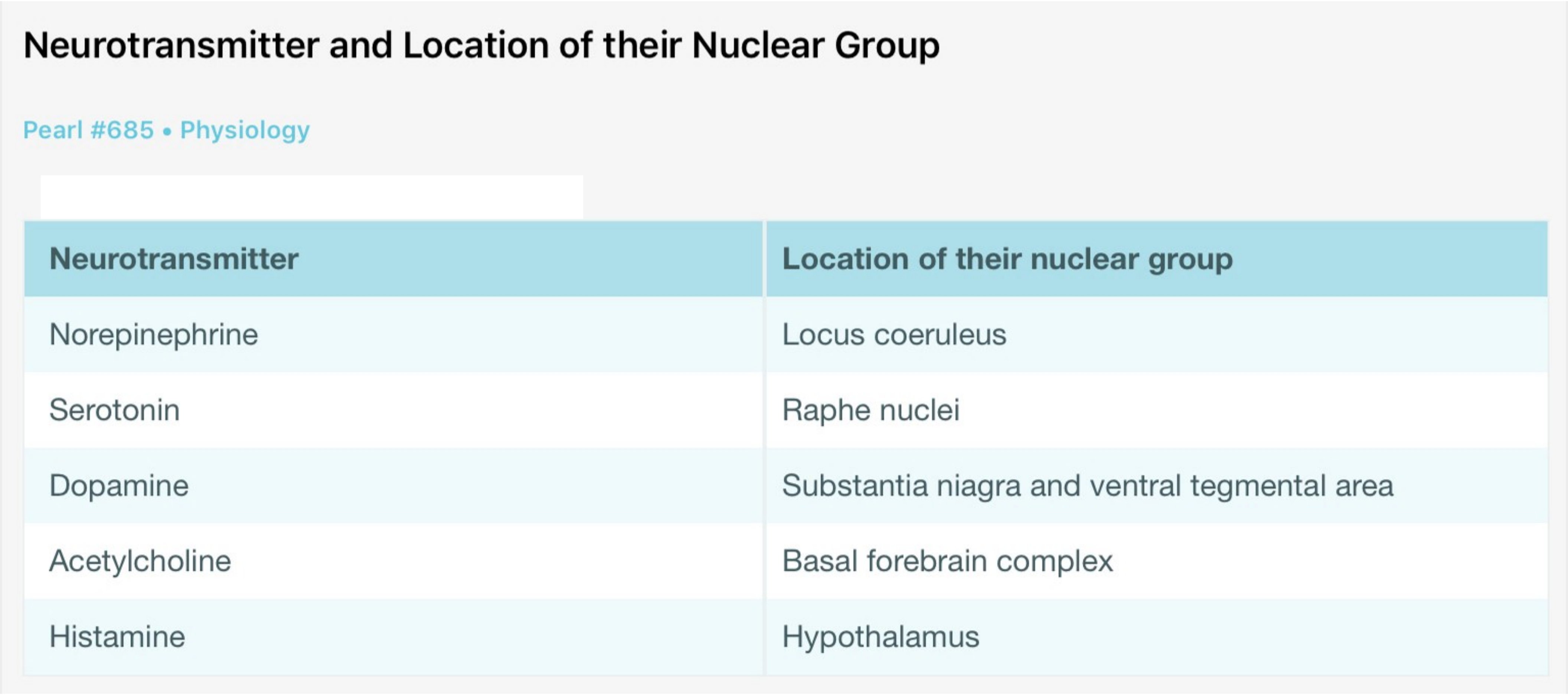
Drugs that effect the neuromuscular transmission



Opioid Receptors

Pearl #686 • Physiology

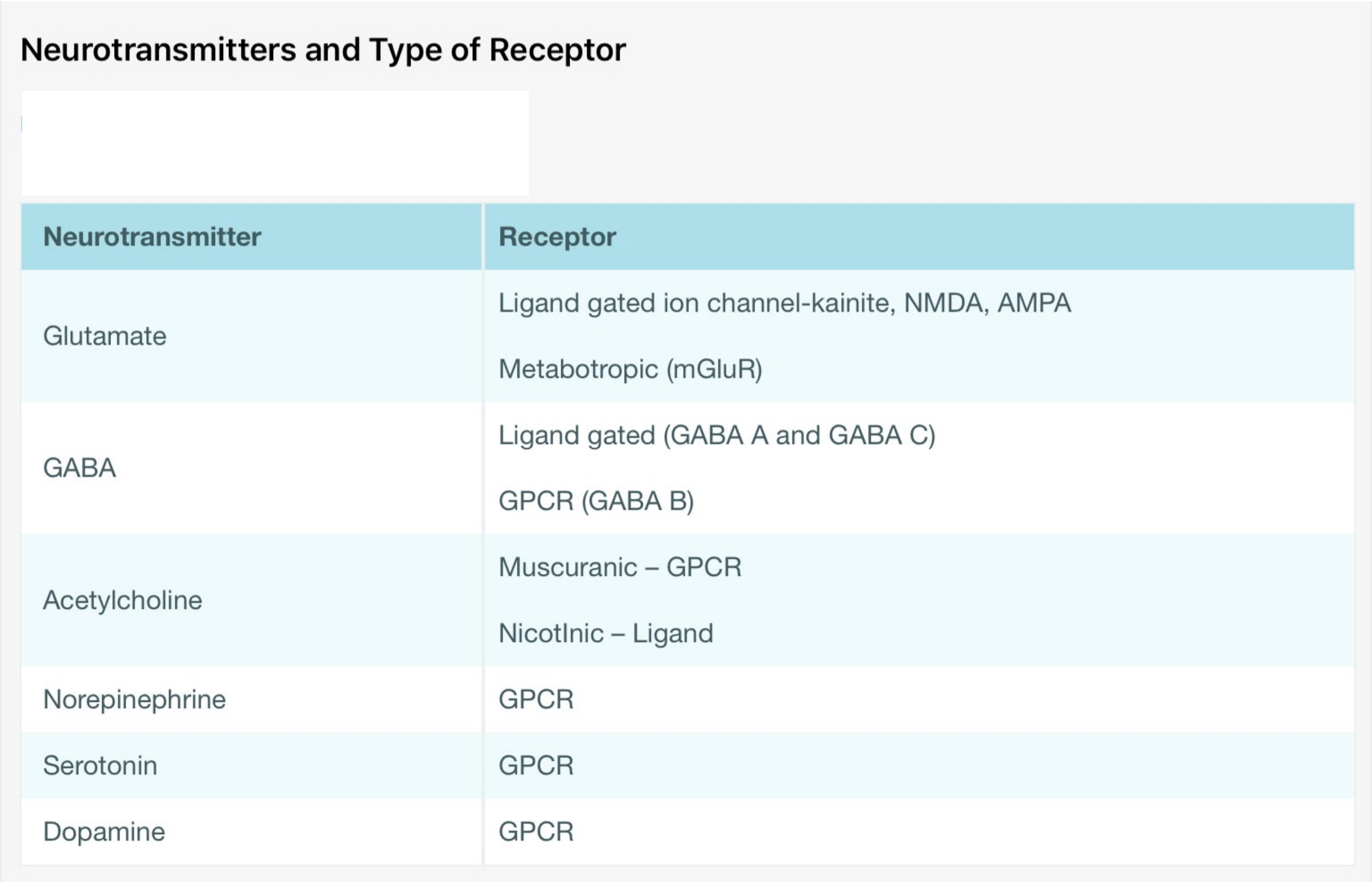
Receptor	Effect
μ	Miosis Urine retention Sedation Slowed GI transit - constipation Supraspinal and spinal analgesia Respiratory depression Muscular rigidity Euphoria Modulation of hormone and neurotransmitter release
δ	Supraspinal and spinal analgesia Modulation of hormone and neurotransmitter release
κ	Slowed GI transit - constipation Supraspinal and spinal analgesia Psychotomimetic effect- Dysphoria



Neurotransmitter and Location of their Nuclear Group

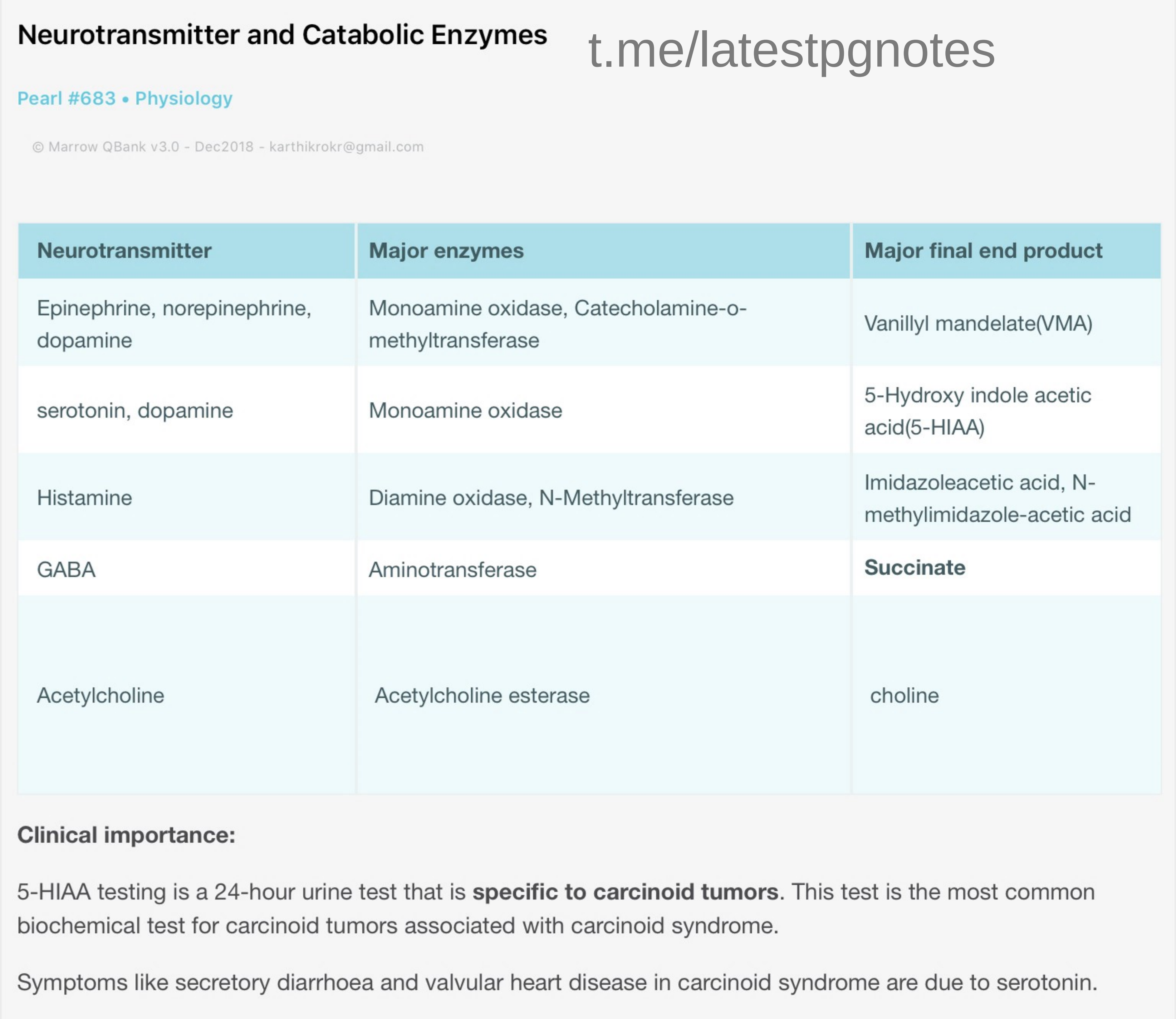
Pearl #685 • Physiology

Neurotransmitter	Location of their nuclear group
Norepinephrine	Locus coeruleus
Serotonin	Raphe nuclei
Dopamine	Substantia niagra and ventral tegmental area
Acetylcholine	Basal forebrain complex
Histamine	Hypothalamus



Neurotransmitters and Type of Receptor

Neurotransmitter	Receptor
Glutamate	Ligand gated ion channel-kainite, NMDA, AMPA Metabotropic (mGluR)
GABA	Ligand gated (GABA A and GABA C) GPCR (GABA B)
Acetylcholine	Muscuranic – GPCR Nicotlnic – Ligand
Norepinephrine	GPCR
Serotonin	GPCR
Dopamine	GPCR



Neurotransmitter and Catabolic Enzymes

Pearl #683 • Physiology

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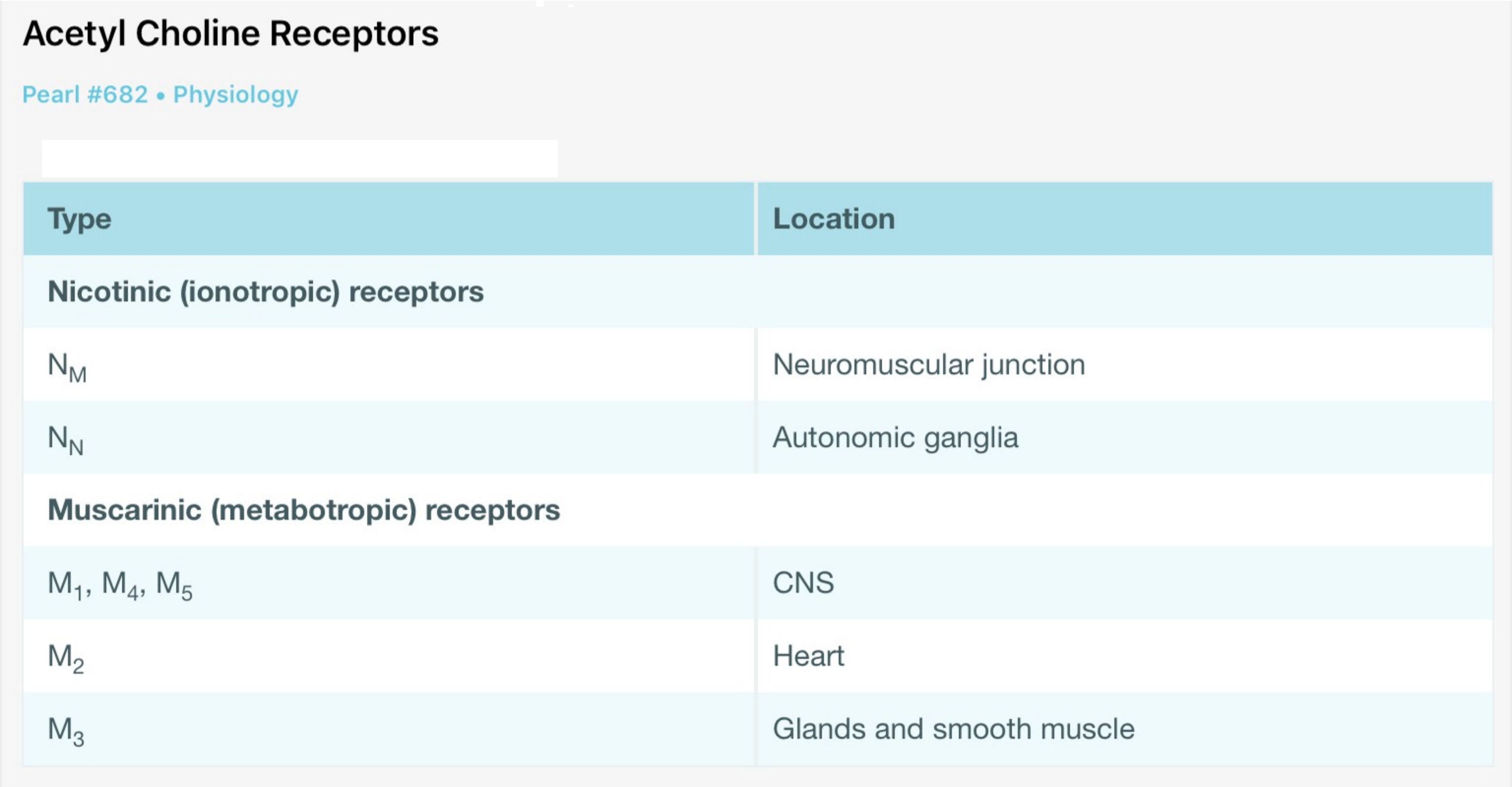
Neurotransmitter	Major enzymes	Major final end product
Epinephrine, norepinephrine, dopamine	Monoamine oxidase, Catecholamine-o-methyltransferase	Vanillyl mandelate(VMA)
serotonin, dopamine	Monoamine oxidase	5-Hydroxy indole acetic acid(5-HIAA)
Histamine	Diamine oxidase, N-Methyltransferase	Imidazoleacetic acid, N-methylimidazole-acetic acid
GABA	Aminotransferase	**Succinate**
Acetylcholine	Acetylcholine esterase	choline

Clinical importance:

5-HIAA testing is a 24-hour urine test that is **specific to carcinoid tumors**. This test is the most common biochemical test for carcinoid tumors associated with carcinoid syndrome.

Symptoms like secretory diarrhoea and valvular heart disease in carcinoid syndrome are due to serotonin.



Acetyl Choline Receptors

Pearl #682 • Physiology

Type	Location
Nicotinic (ionotropic) receptors	
N_M	Neuromuscular junction
N_N	Autonomic ganglia
Muscarinic (metabotropic) receptors	
M_1, M_4, M_5	CNS
M_2	Heart
M_3	Glands and smooth muscle

Class I

Acetylcholine

Class II: The Amines

Norepinephrine

Epinephrine

Dopamine

Serotonin

Histamine

Class III: Amino Acids

Gamma-aminobutyric acid (GABA)

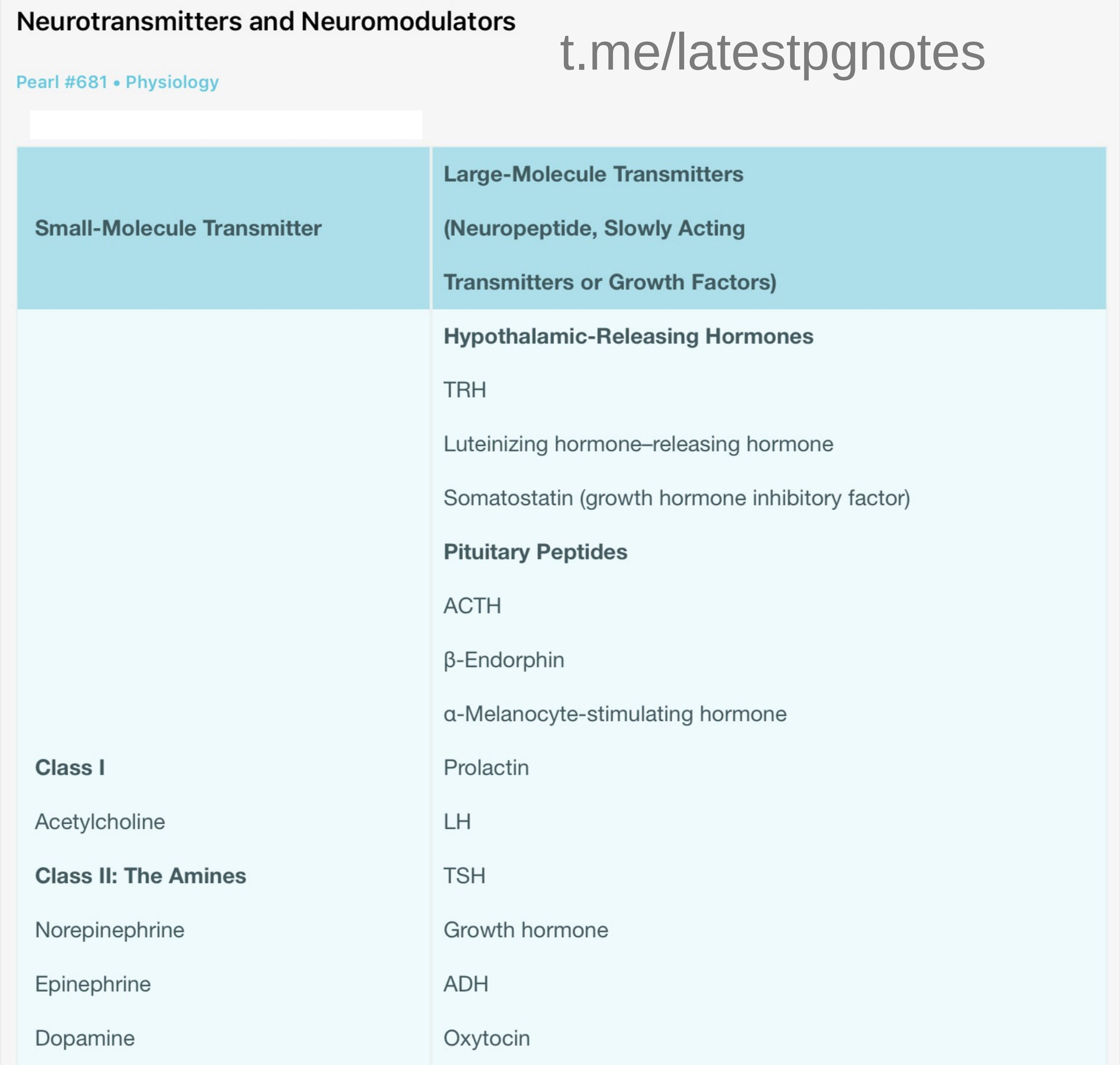
Glycine

Glutamate

Aspartate

Class IV

Nitric oxide



Neurotransmitters and Neuromodulators

Pearl #681 • Physiology

Small-Molecule Transmitter	Large-Molecule Transmitters (Neuropeptide, Slowly Acting Transmitters or Growth Factors)
	Hypothalamic-Releasing Hormones
	TRH
	Luteinizing hormone–releasing hormone
	Somatostatin (growth hormone inhibitory factor)
	Pituitary Peptides
	ACTH
	β-Endorphin
	α-Melanocyte-stimulating hormone
Class I	Prolactin
Acetylcholine	LH
Class II: The Amines	TSH
Norepinephrine	Growth hormone
Epinephrine	ADH
Dopamine	Oxytocin

Peptides that Act on Gut and Brain

Enkephalin

Substance P

Gastrin

Cholecystokinin

VIP

Nerve growth factor

Brain-derived neurotropic factor

Neurotensin

Insulin

Glucagon

From Other Tissues

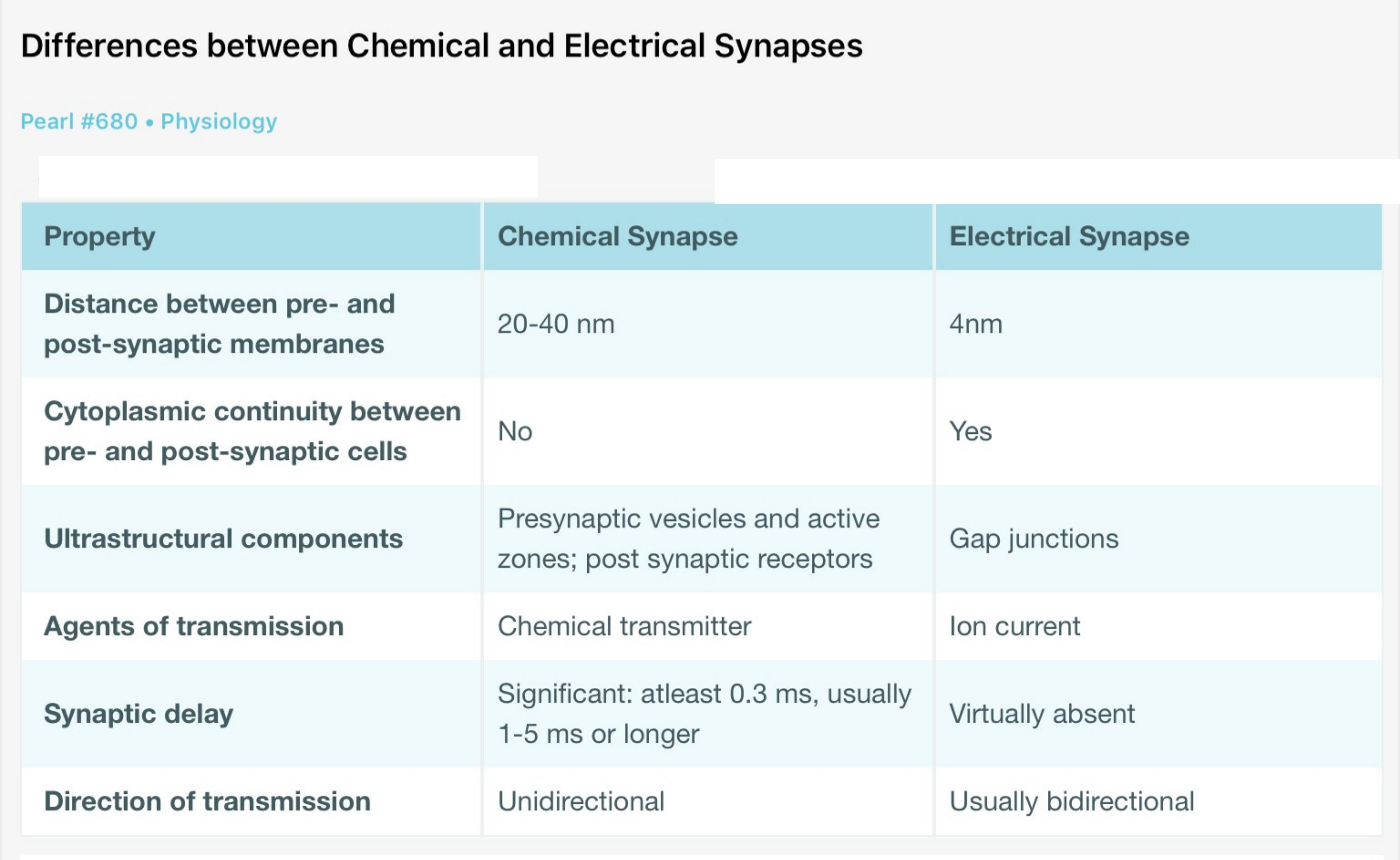
Angiotensin II

Bradykinin

Carnosine

Sleep peptides

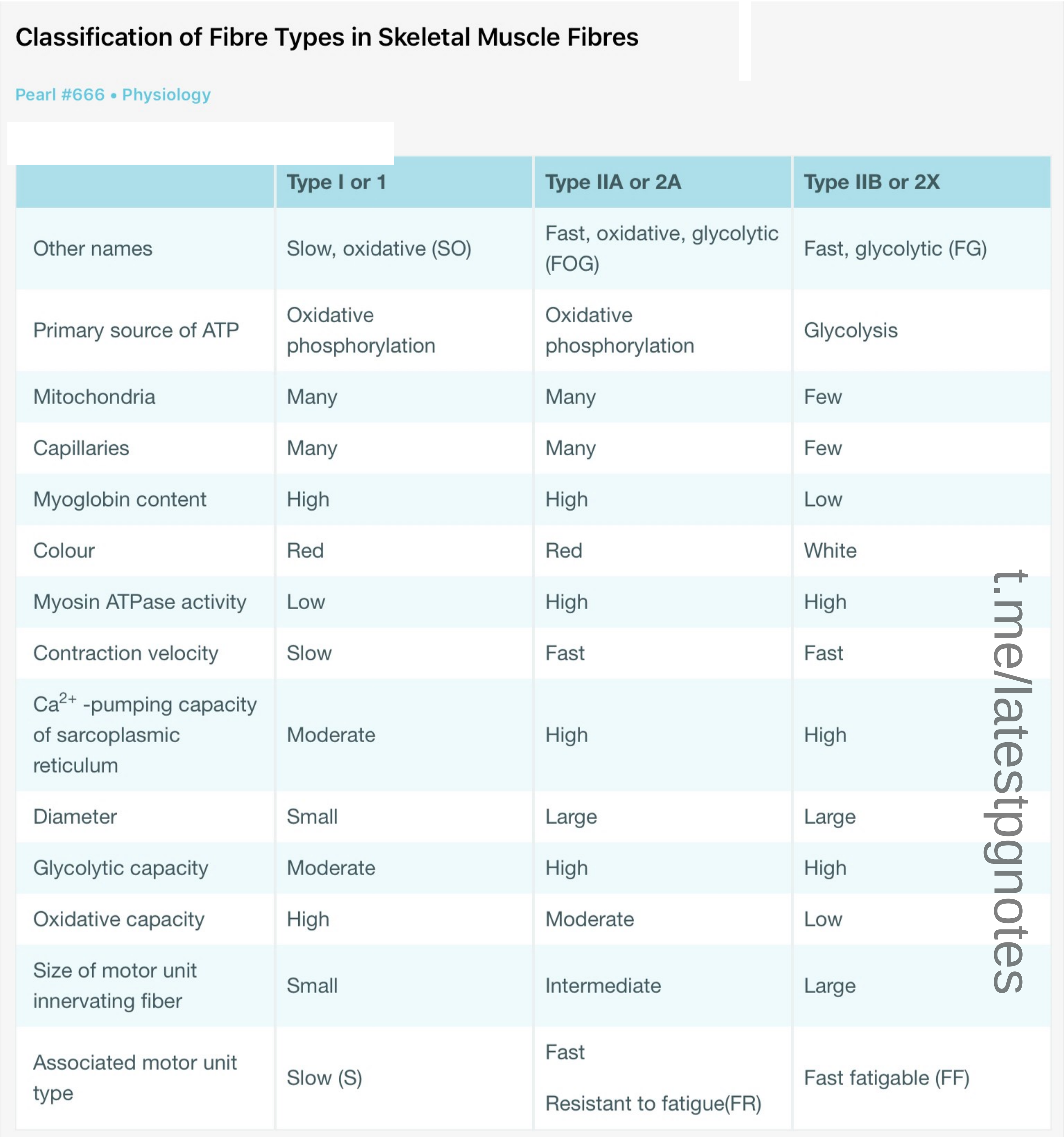
Calcitonin



Differences between Chemical and Electrical Synapses

Pearl #680 • Physiology

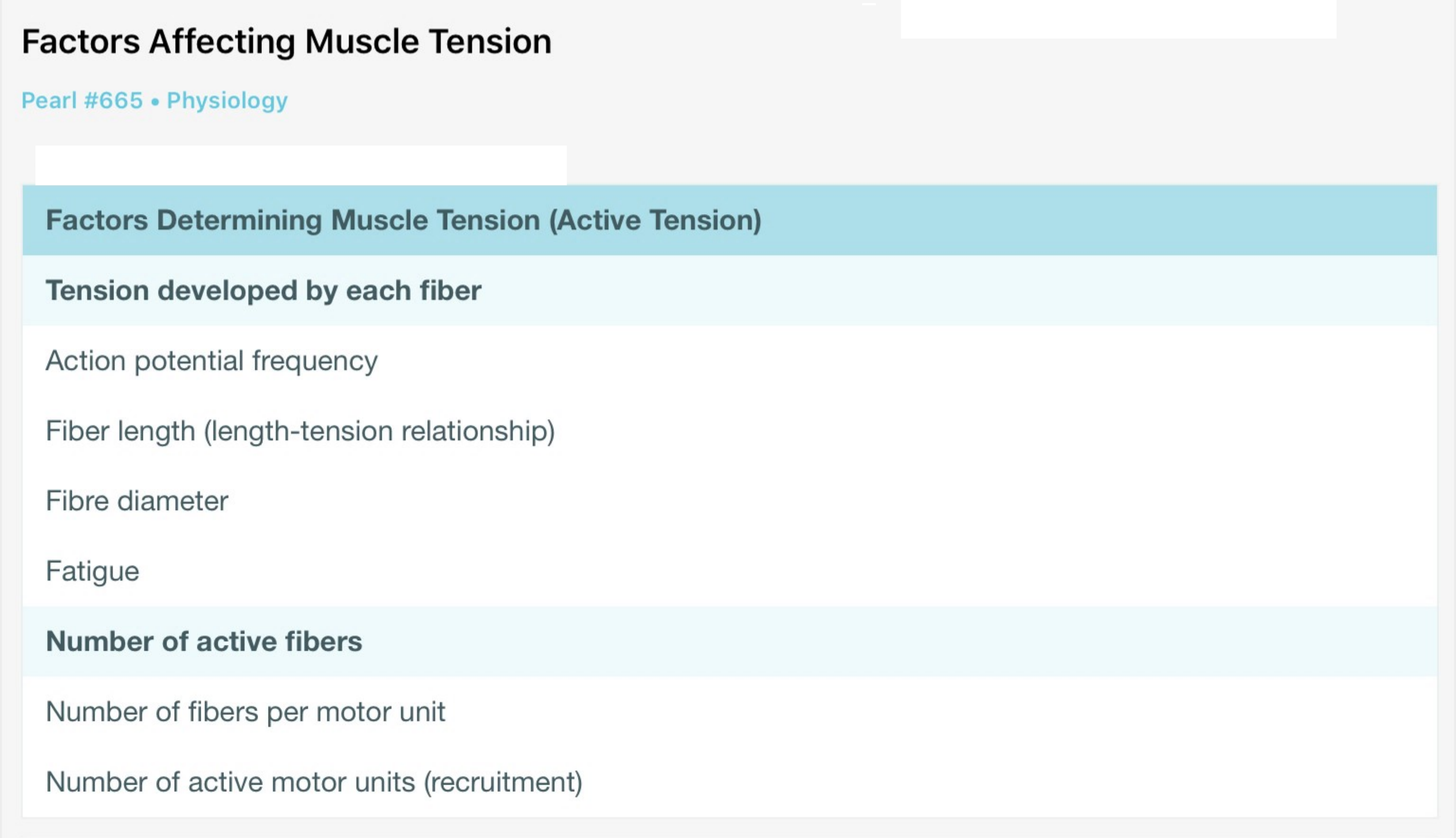
Property	Chemical Synapse	Electrical Synapse
Distance between pre- and post-synaptic membranes	20-40 nm	4nm
Cytoplasmic continuity between pre- and post-synaptic cells	No	Yes
Ultrastructural components	Presynaptic vesicles and active zones; post synaptic receptors	Gap junctions
Agents of transmission	Chemical transmitter	Ion current
Synaptic delay	Significant: atleast 0.3 ms, usually 1-5 ms or longer	Virtually absent
Direction of transmission	Unidirectional	Usually bidirectional



Classification of Fibre Types in Skeletal Muscle Fibres

Pearl #666 • Physiology

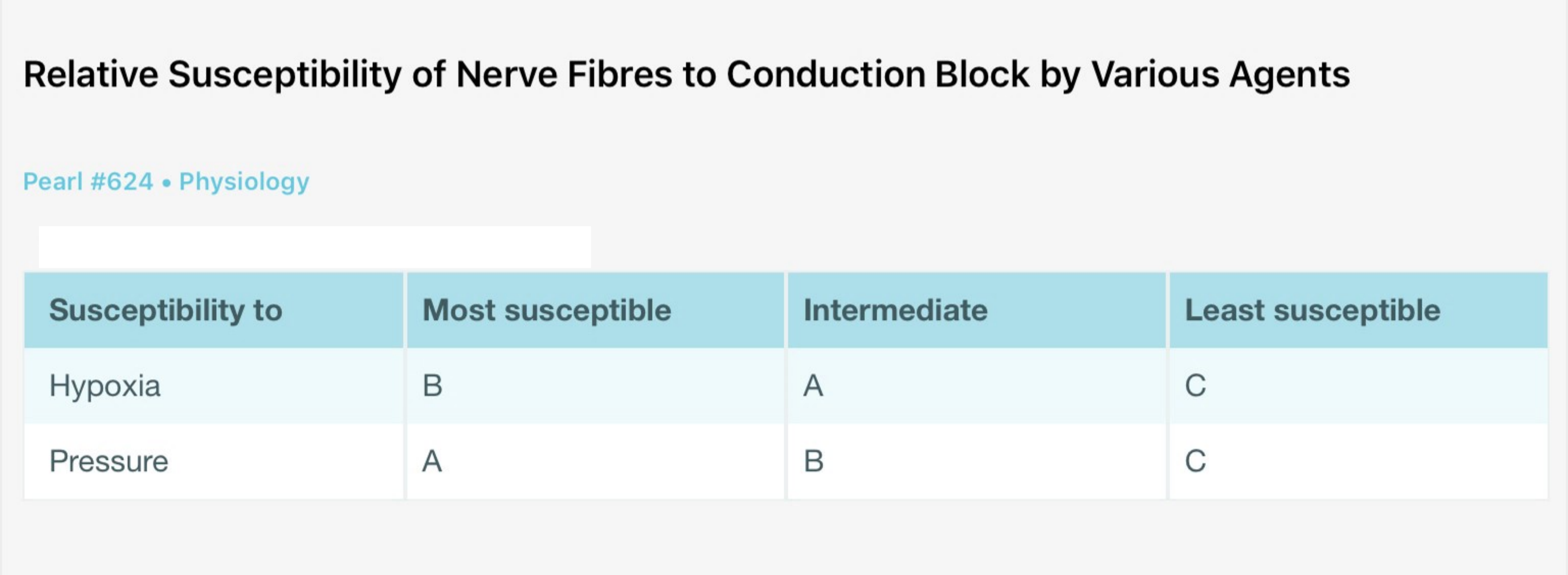
	Type I or 1	Type IIA or 2A	Type IIB or 2X
Other names	Slow, oxidative (SO)	Fast, oxidative, glycolytic (FOG)	Fast, glycolytic (FG)
Primary source of ATP	Oxidative phosphorylation	Oxidative phosphorylation	Glycolysis
Mitochondria	Many	Many	Few
Capillaries	Many	Many	Few
Myoglobin content	High	High	Low
Colour	Red	Red	White
Myosin ATPase activity	Low	High	High
Contraction velocity	Slow	Fast	Fast
Ca^{2+} -pumping capacity of sarcoplasmic reticulum	Moderate	High	High
Diameter	Small	Large	Large
Glycolytic capacity	Moderate	High	High
Oxidative capacity	High	Moderate	Low
Size of motor unit innervating fiber	Small	Intermediate	Large
Associated motor unit type	Slow (S)	Fast Resistant to fatigue(FR)	Fast fatigable (FF)



Factors Affecting Muscle Tension

Pearl #665 • Physiology

Factors Determining Muscle Tension (Active Tension)
Tension developed by each fiber
Action potential frequency
Fiber length (length-tension relationship)
Fibre diameter
Fatigue
Number of active fibers
Number of fibers per motor unit
Number of active motor units (recruitment)



Relative Susceptibility of Nerve Fibres to Conduction Block by Various Agents

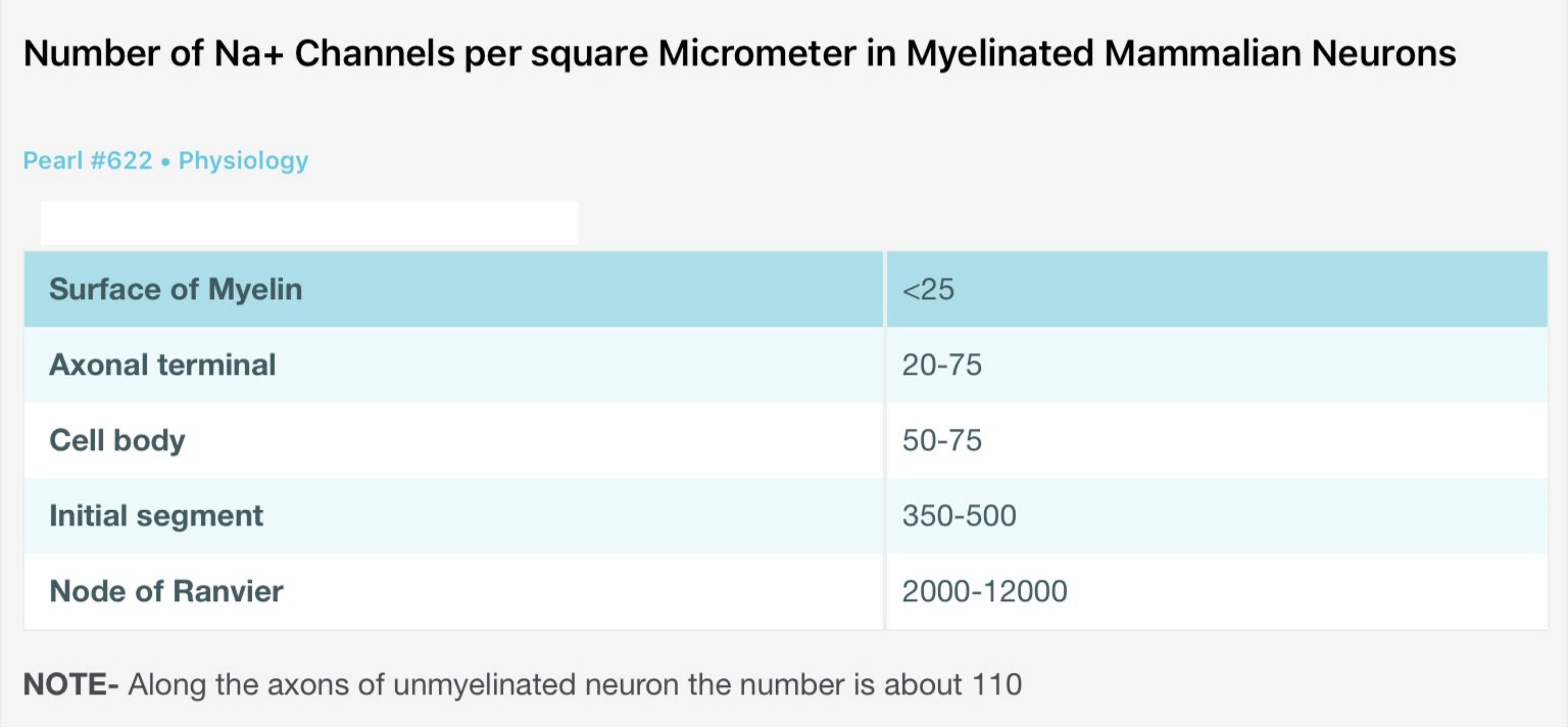
Pearl #624 • Physiology

Susceptibility to	Most susceptible	Intermediate	Least susceptible
Hypoxia	B	A	C
Pressure	A	B	C

Types of Mammalian Nerve Fibres (Erlanger and Gasser's Classification)

Pearl #623 • Physiology

Fiber type	Function	Fiber diameter(μm)	Conduction velocity(m/s)	Spike duration(ms)
Aα	Proprioception, somatic motor	12-20	70-120	
Aβ	Touch, pressure	5-12	30-70	0.4-0.5
Aγ	Motor to muscle spindles	3-6	15-30	
Aδ	Pain, temperature	2-5	12-30	
B	Preganglionic autonomic	<3	3-15	1.2
C Dorsal root	Pain, temperature	0.4-1.2	0.5-2	2
C Sympathetic	Post ganglionic sympathetic	0.3-1.3	0.7-2.3	2

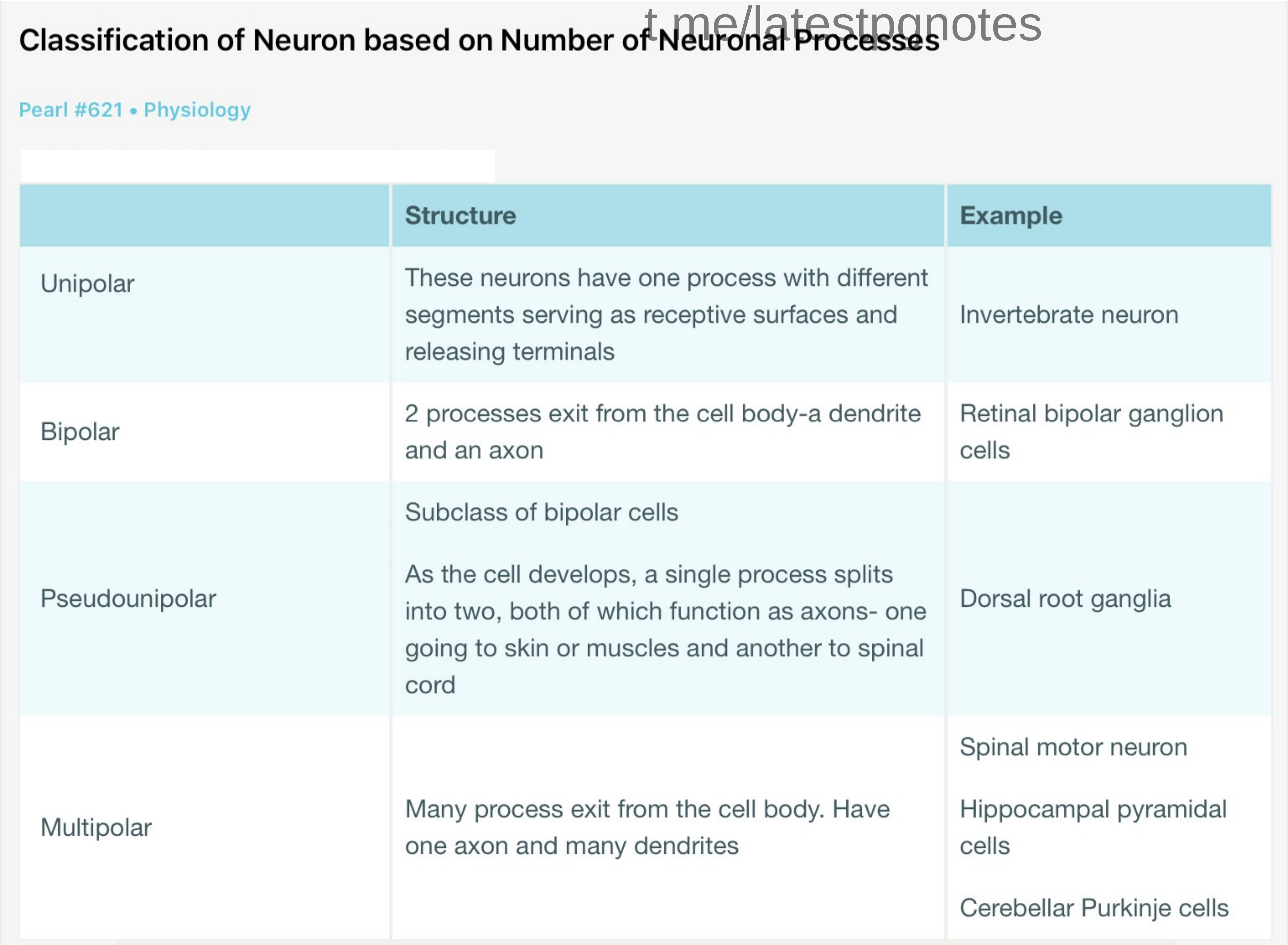


Number of Na+ Channels per square Micrometer in Myelinated Mammalian Neurons

Pearl #622 • Physiology

Surface of Myelin	<25
Axonal terminal	20-75
Cell body	50-75
Initial segment	350-500
Node of Ranvier	2000-12000

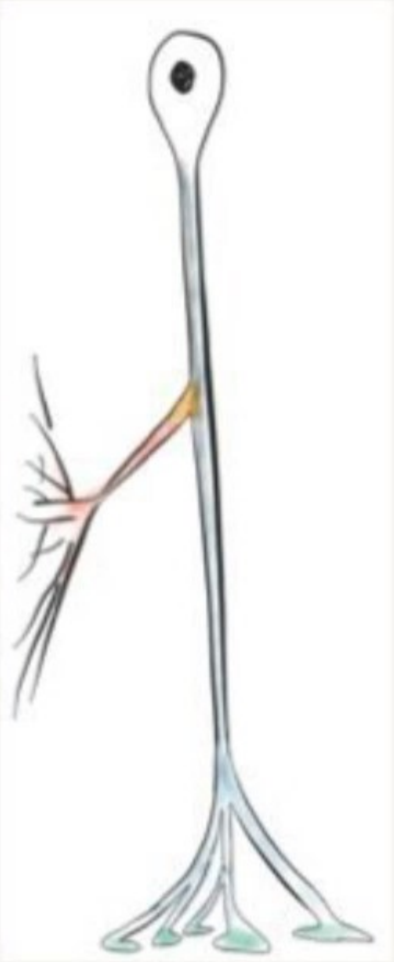
NOTE- Along the axons of unmyelinated neuron the number is about 110



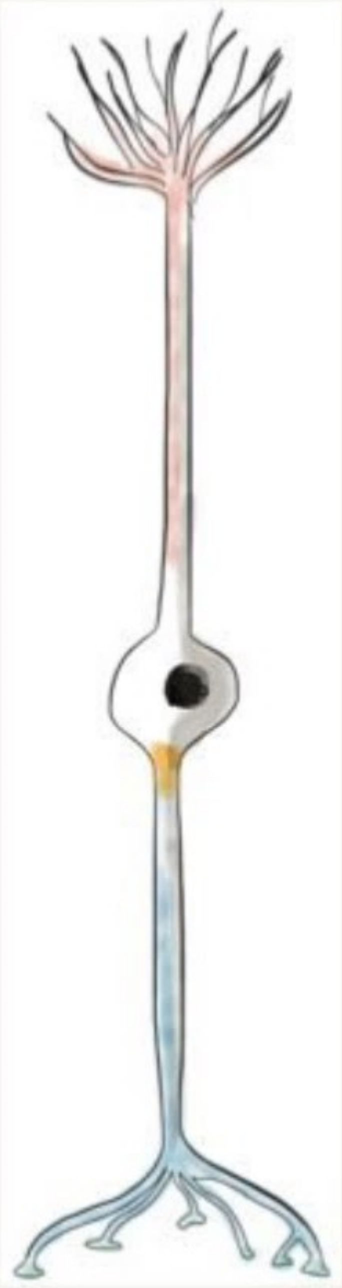
Classification of Neuron based on Number of Neuronal Processes

Pearl #621 • Physiology

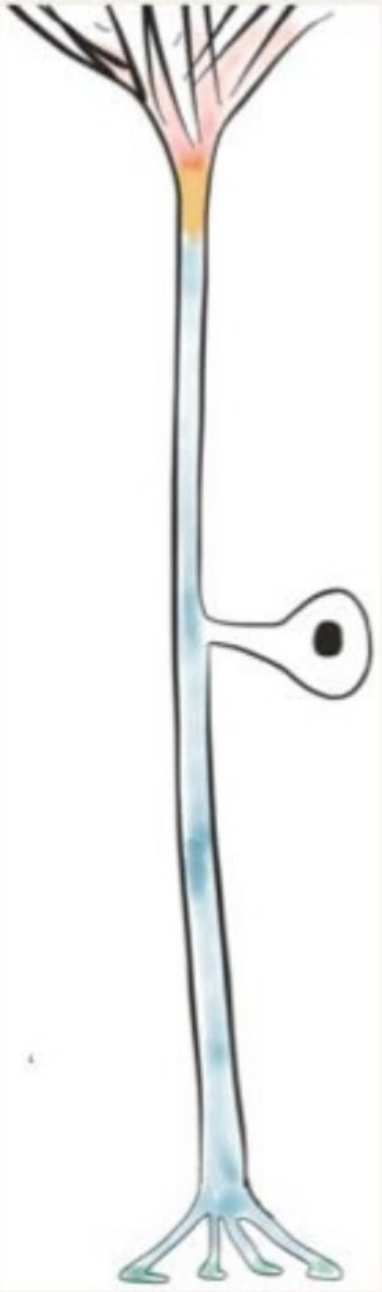
	Structure	Example
Unipolar	These neurons have one process with different segments serving as receptive surfaces and releasing terminals	Invertebrate neuron
Bipolar	2 processes exit from the cell body-a dendrite and an axon	Retinal bipolar ganglion cells
Pseudounipolar	Subclass of bipolar cells As the cell develops, a single process splits into two, both of which function as axons- one going to skin or muscles and another to spinal cord	Dorsal root ganglia
Multipolar	Many process exit from the cell body. Have one axon and many dendrites	Spinal motor neuron Hippocampal pyramidal cells Cerebellar Purkinje cells



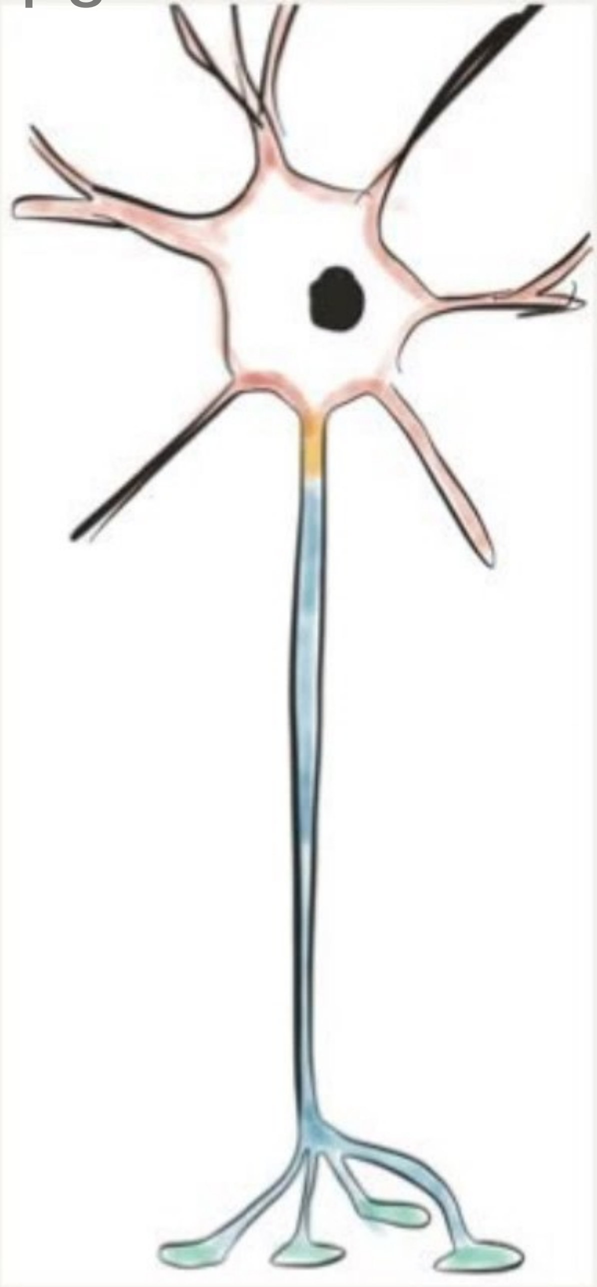
Unipolar



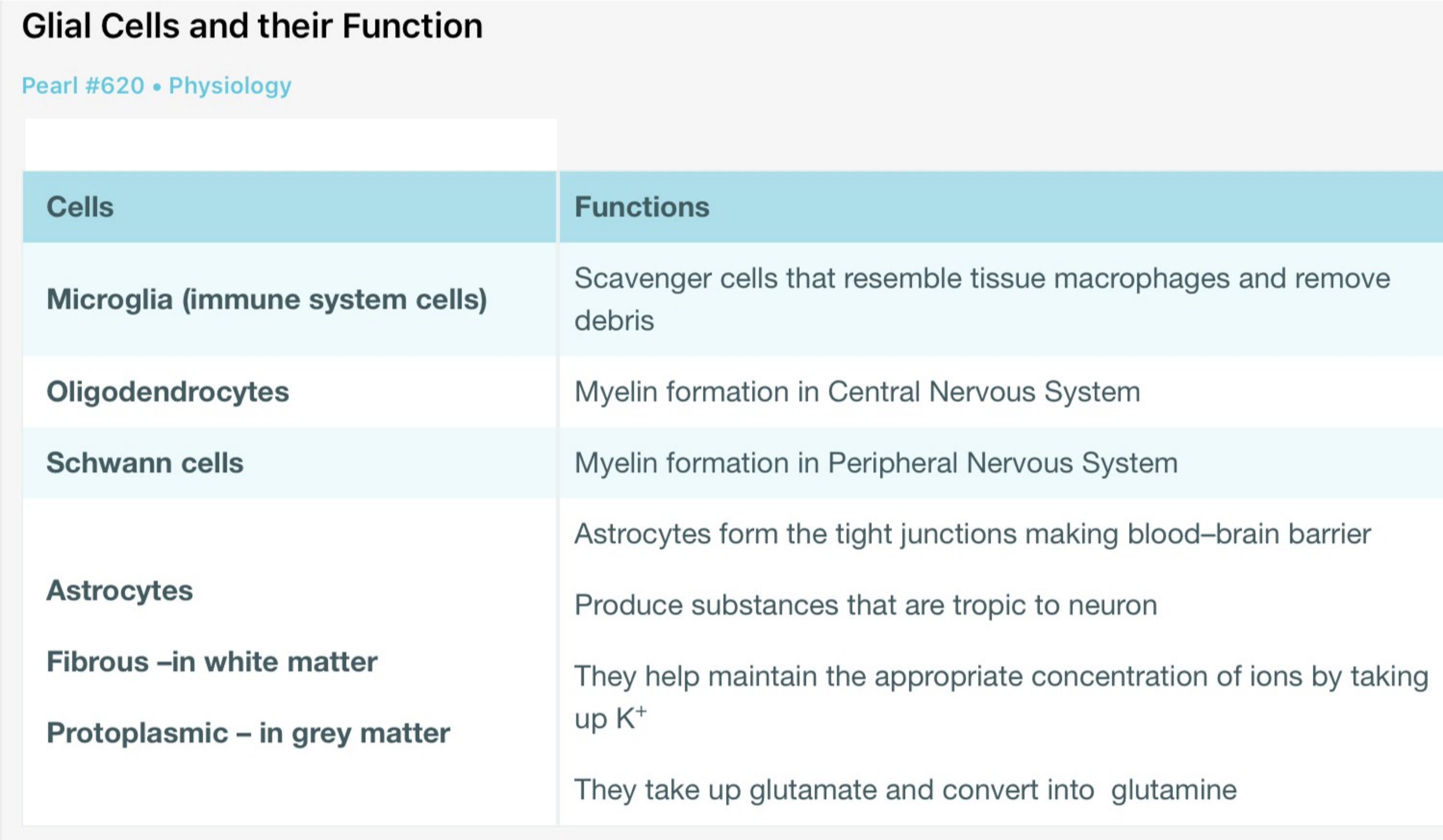
Bipolar



Pseudo-unipolar



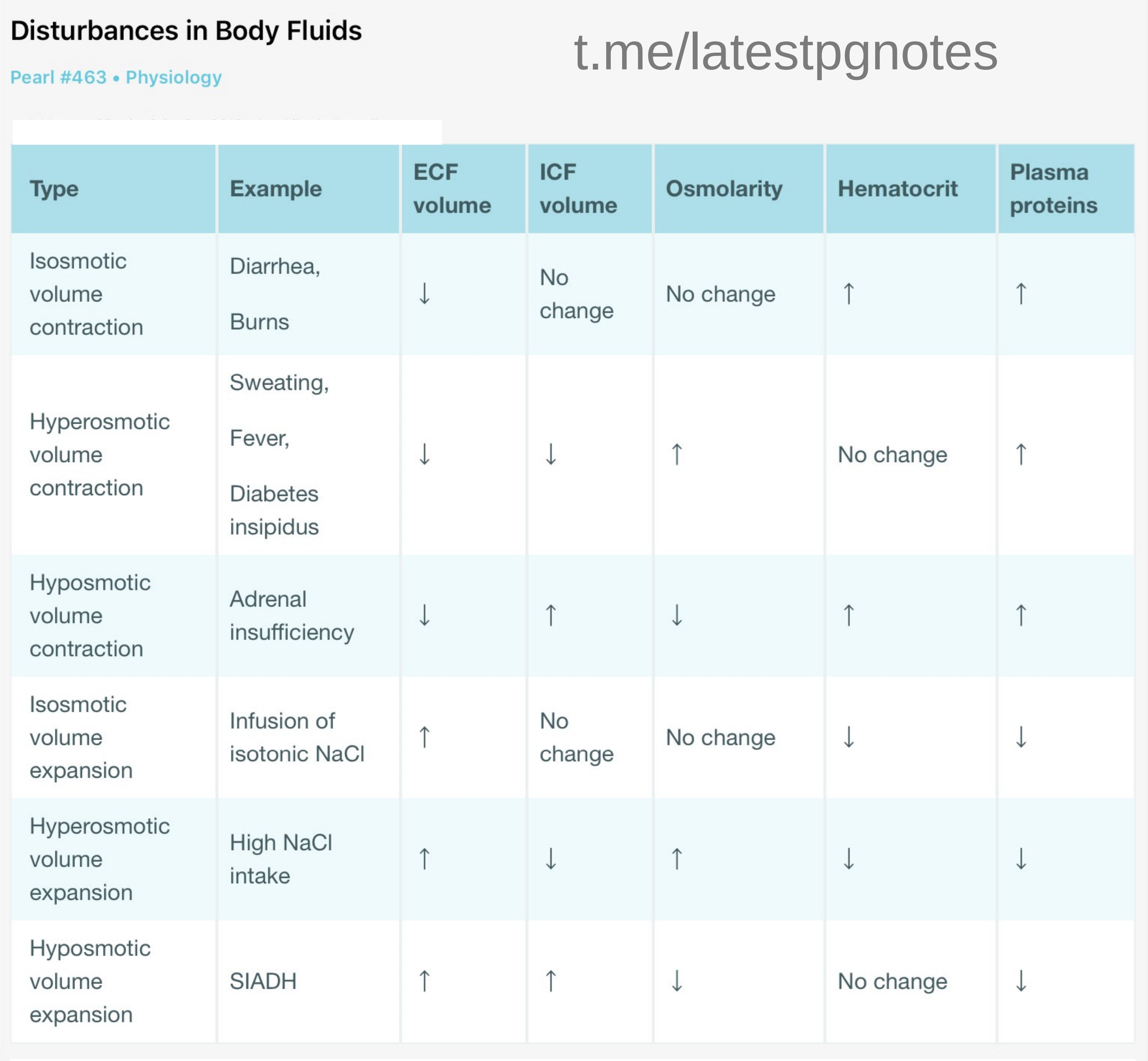
Multipolar



Glial Cells and their Function

Pearl #620 • Physiology

Cells	Functions
Microglia (immune system cells)	Scavenger cells that resemble tissue macrophages and remove debris
Oligodendrocytes	Myelin formation in Central Nervous System
Schwann cells	Myelin formation in Peripheral Nervous System
Astrocytes **Fibrous –in white matter** **Protoplasmic – in grey matter**	Astrocytes form the tight junctions making blood–brain barrier Produce substances that are tropic to neuron They help maintain the appropriate concentration of ions by taking up K^+ They take up glutamate and convert into glutamine



Disturbances in Body Fluids

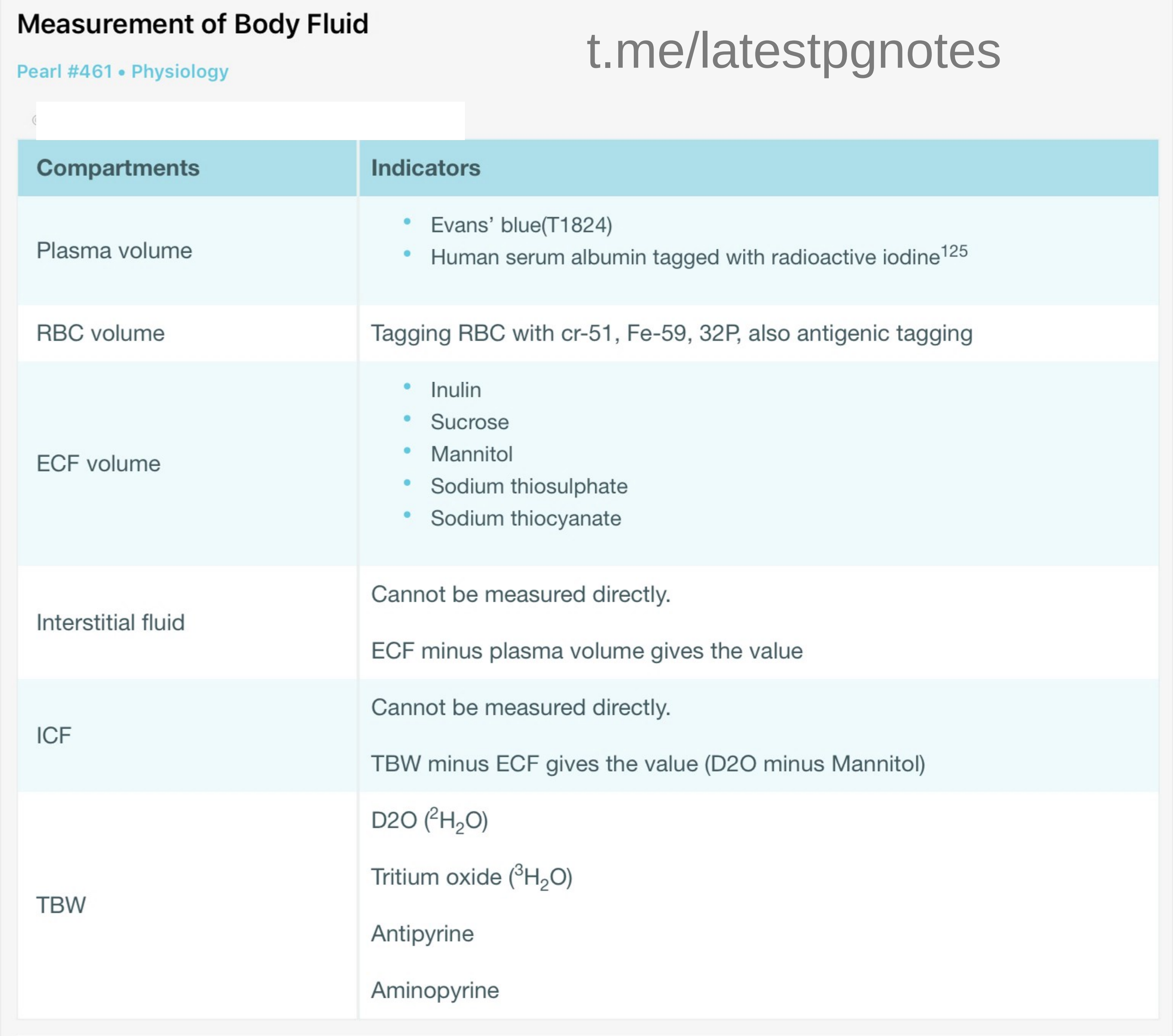
Pearl #463 • Physiology

Type	Example	ECF volume	ICF volume	Osmolarity	Hematocrit	Plasma proteins
Isosmotic volume contraction	Diarrhea, Burns	↓	No change	No change	↑	↑
Hyperosmotic volume contraction	Sweating, Fever, Diabetes insipidus	↓	↓	↑	No change	↑
Hyposmotic volume contraction	Adrenal insufficiency	↓	↑	↓	↑	↑
Isosmotic volume expansion	Infusion of isotonic NaCl	↑	No change	No change	↓	↓
Hyperosmotic volume expansion	High NaCl intake	↑	↓	↑	↓	↓
Hyposmotic volume expansion	SIADH	↑	↑	↓	No change	↓

Daily Fluid Intake and Output

Pearl #462 • Physiology

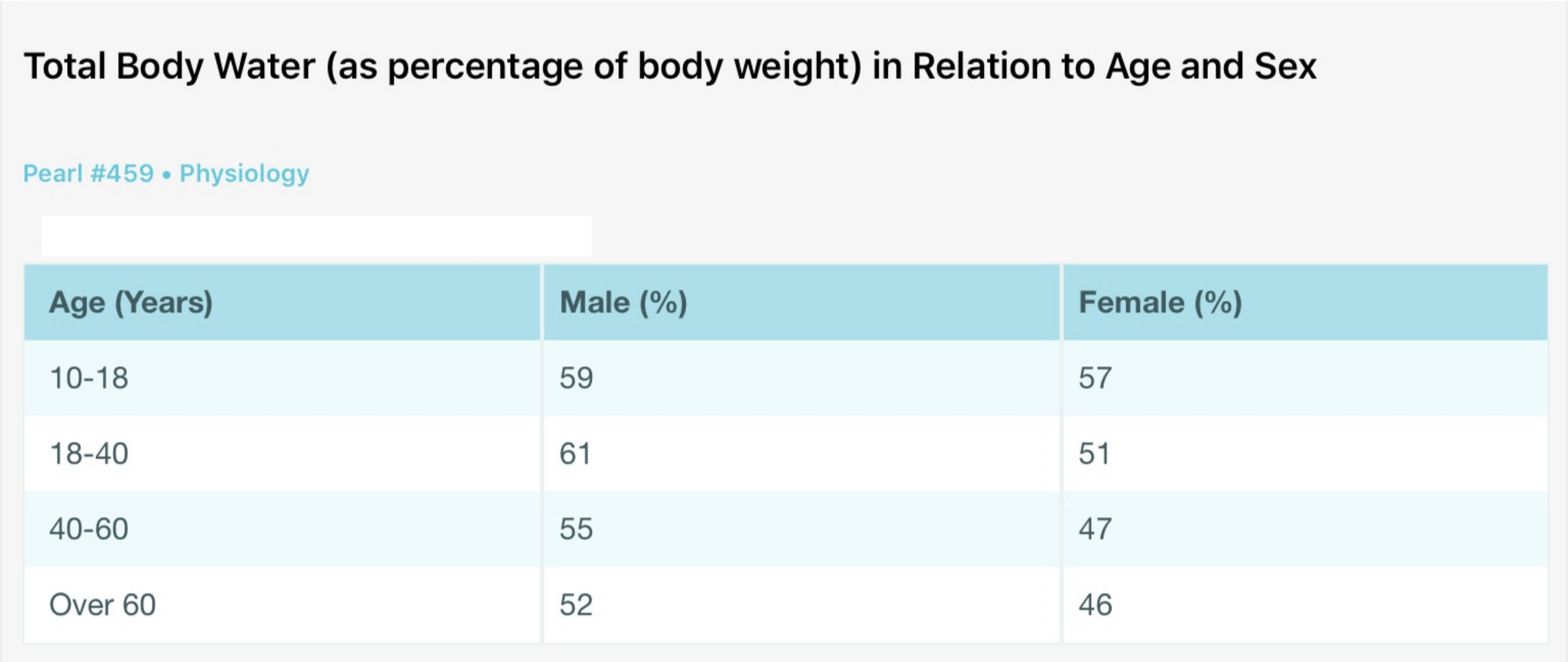
	Normal (in mL/day)	Prolonged, Heavy Exercise (mL/day)
Intake		
Fluids ingested	2100	-
From metabolism	200	200
Total intake	**2300**	**-**
Output		
Insensible loss : skin	350	350
Insensible loss : lungs	350	650
Sweat	100	5000
Feces	100	100
Urine	1400	500
Total output	**2300**	**6600**



Measurement of Body Fluid

Pearl #461 • Physiology

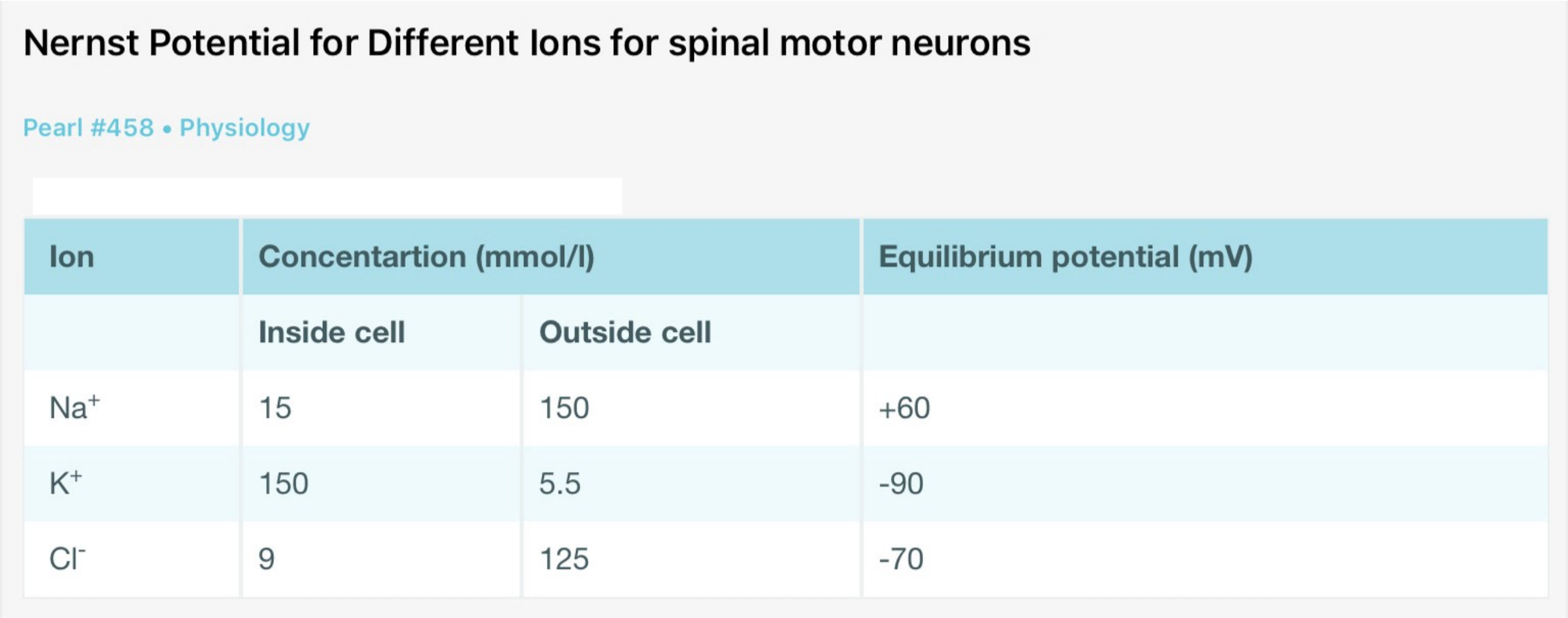
Compartments	Indicators
Plasma volume	• Evans' blue(T1824) • Human serum albumin tagged with radioactive iodine^{125}
RBC volume	Tagging RBC with cr-51, Fe-59, 32P, also antigenic tagging
ECF volume	• Inulin • Sucrose • Mannitol • Sodium thiosulphate • Sodium thiocyanate
Interstitial fluid	Cannot be measured directly. ECF minus plasma volume gives the value
ICF	Cannot be measured directly. TBW minus ECF gives the value (D2O minus Mannitol)
TBW	D2O (^2H_2O) Tritium oxide (^3H_2O) Antipyrine Aminopyrine



Total Body Water (as percentage of body weight) in Relation to Age and Sex

Pearl #459 • Physiology

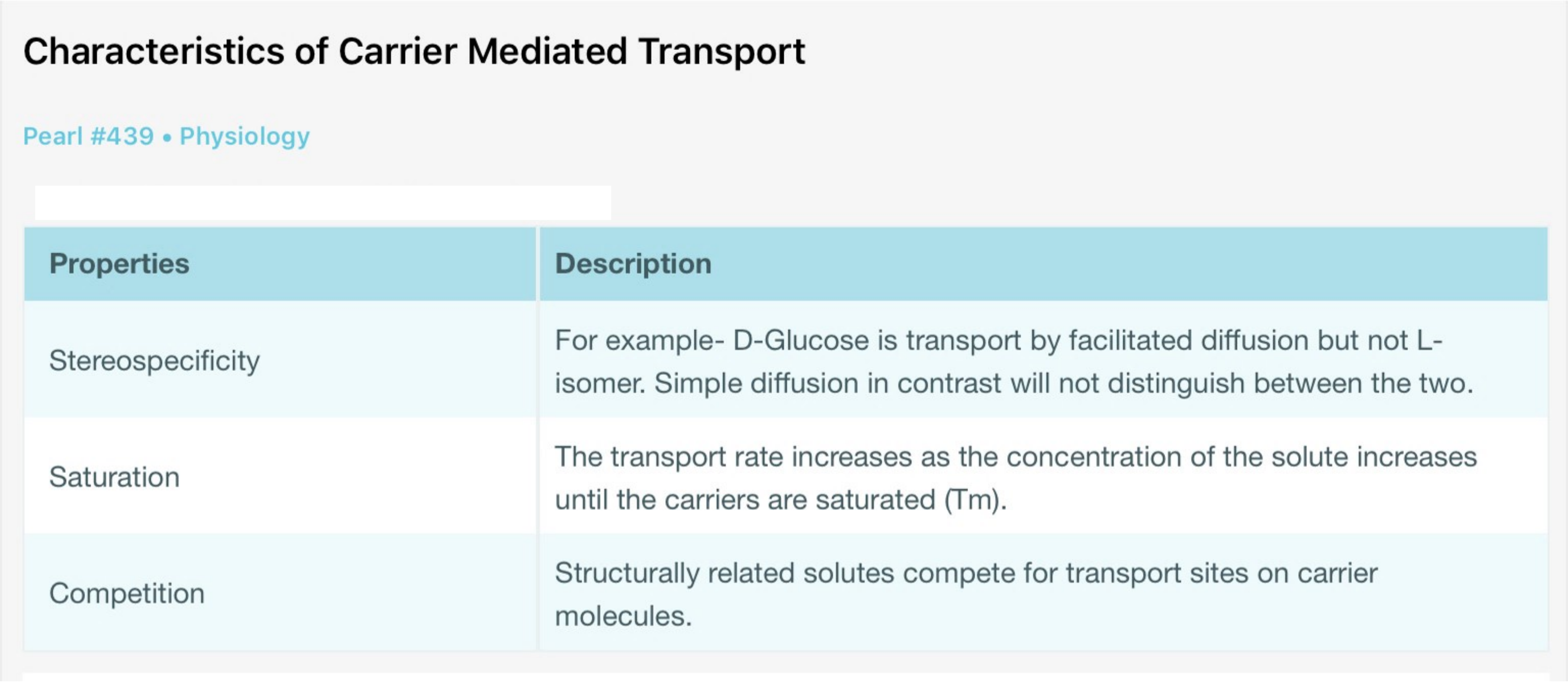
Age (Years)	Male (%)	Female (%)
10-18	59	57
18-40	61	51
40-60	55	47
Over 60	52	46



Nernst Potential for Different Ions for spinal motor neurons

Pearl #458 • Physiology

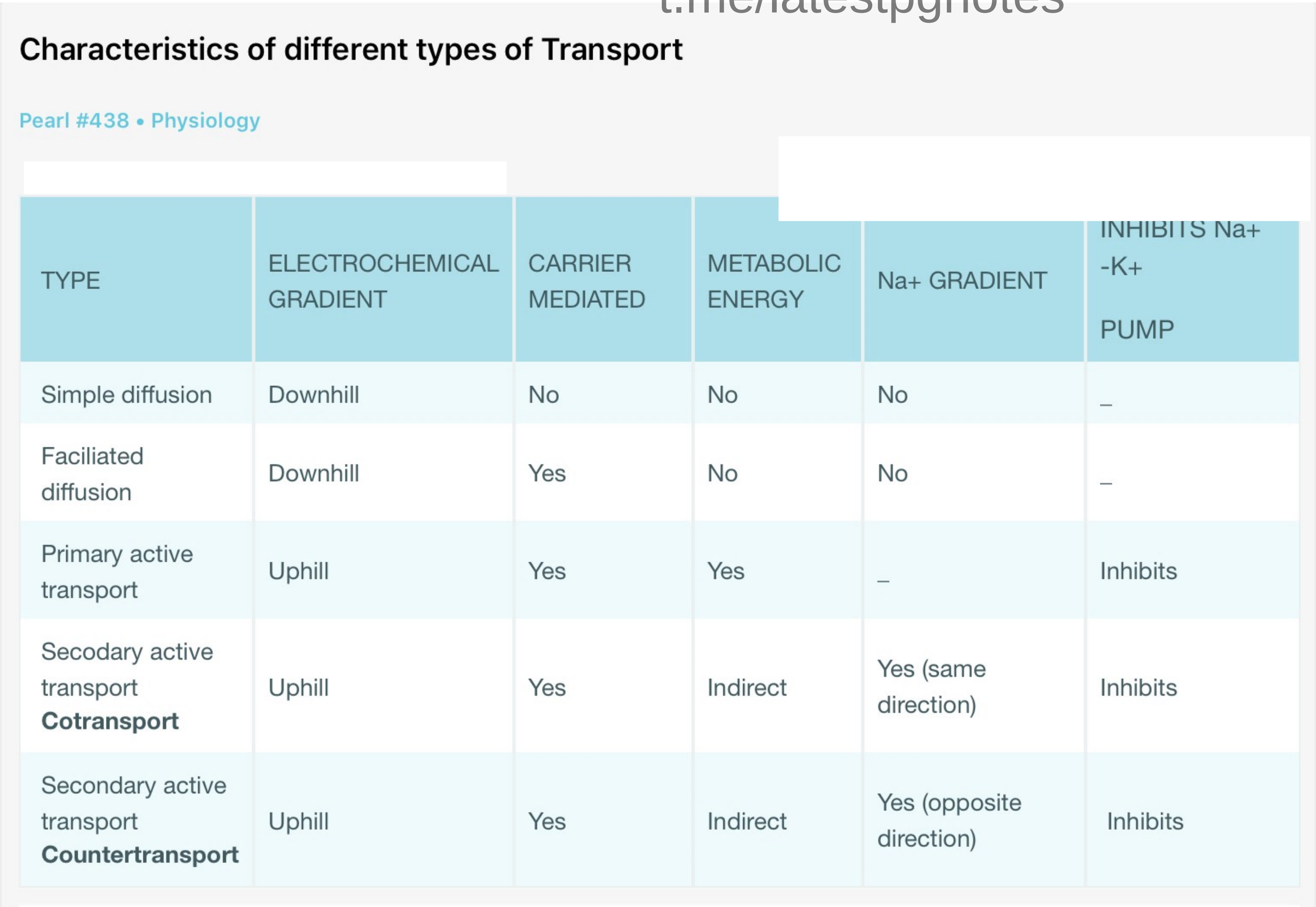
Ion	Concentartion (mmol/l)		Equilibrium potential (mV)
	Inside cell	**Outside cell**	
Na^+	15	150	+60
K^+	150	5.5	-90
Cl^-	9	125	-70



Characteristics of Carrier Mediated Transport

Pearl #439 • Physiology

Properties	Description
Stereospecificity	For example- D-Glucose is transport by facilitated diffusion but not L-isomer. Simple diffusion in contrast will not distinguish between the two.
Saturation	The transport rate increases as the concentration of the solute increases until the carriers are saturated (Tm).
Competition	Structurally related solutes compete for transport sites on carrier molecules.



Characteristics of different types of Transport

Pearl #438 • Physiology

TYPE	ELECTROCHEMICAL GRADIENT	CARRIER MEDIATED	METABOLIC ENERGY	Na+ GRADIENT	INHIBITS Na+ -K+ PUMP
Simple diffusion	Downhill	No	No	No	_
Faciliated diffusion	Downhill	Yes	No	No	_
Primary active transport	Uphill	Yes	Yes	_	Inhibits
Secodary active transport **Cotransport**	Uphill	Yes	Indirect	Yes (same direction)	Inhibits
Secondary active transport **Countertransport**	Uphill	Yes	Indirect	Yes (opposite direction)	Inhibits

Factors influencing the rate of net diffusion of a substance across a membrane

Pearl #437 • Physiology

Fick's Law of Diffusion → $J = -DA\left({}^{\Delta c}/_{\Delta x}\right)$

where,

J is the net rate of diffusion,

D is the diffusion coefficient,

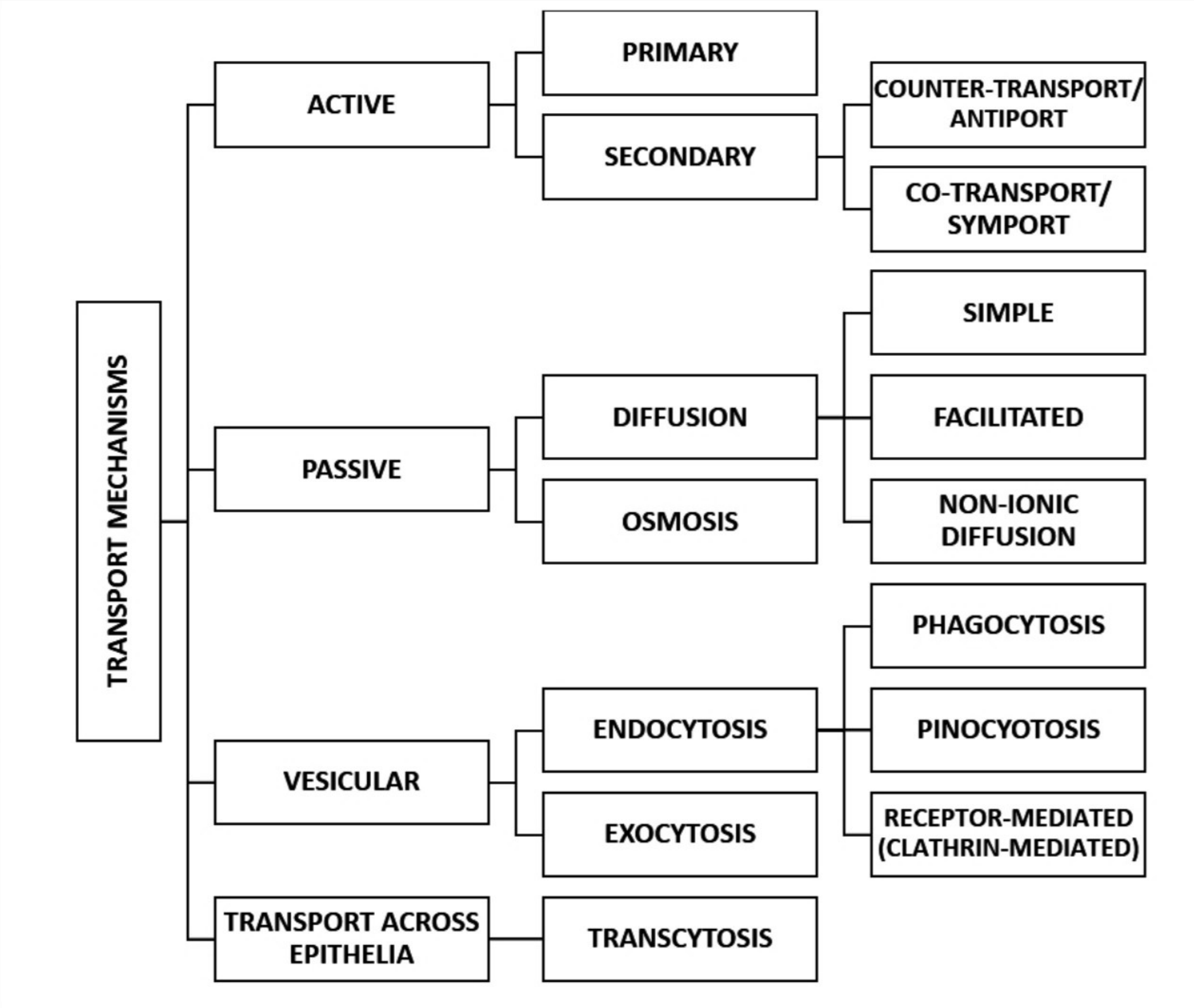
A is the area, and

$\Delta c/\Delta x$ is the concentration gradient.

Factors	Effect on diffusion
↑ Thickness of the membrane	↓
↑ Lipid Solubility	↑
↑ Temperature	↑
↑ Size of the molecule	↓
↑ Area of the Membrane	↑
↑ Distribution of Protein Channels	↑

Transport across the cell membrane

Pearl #435 • Physiology



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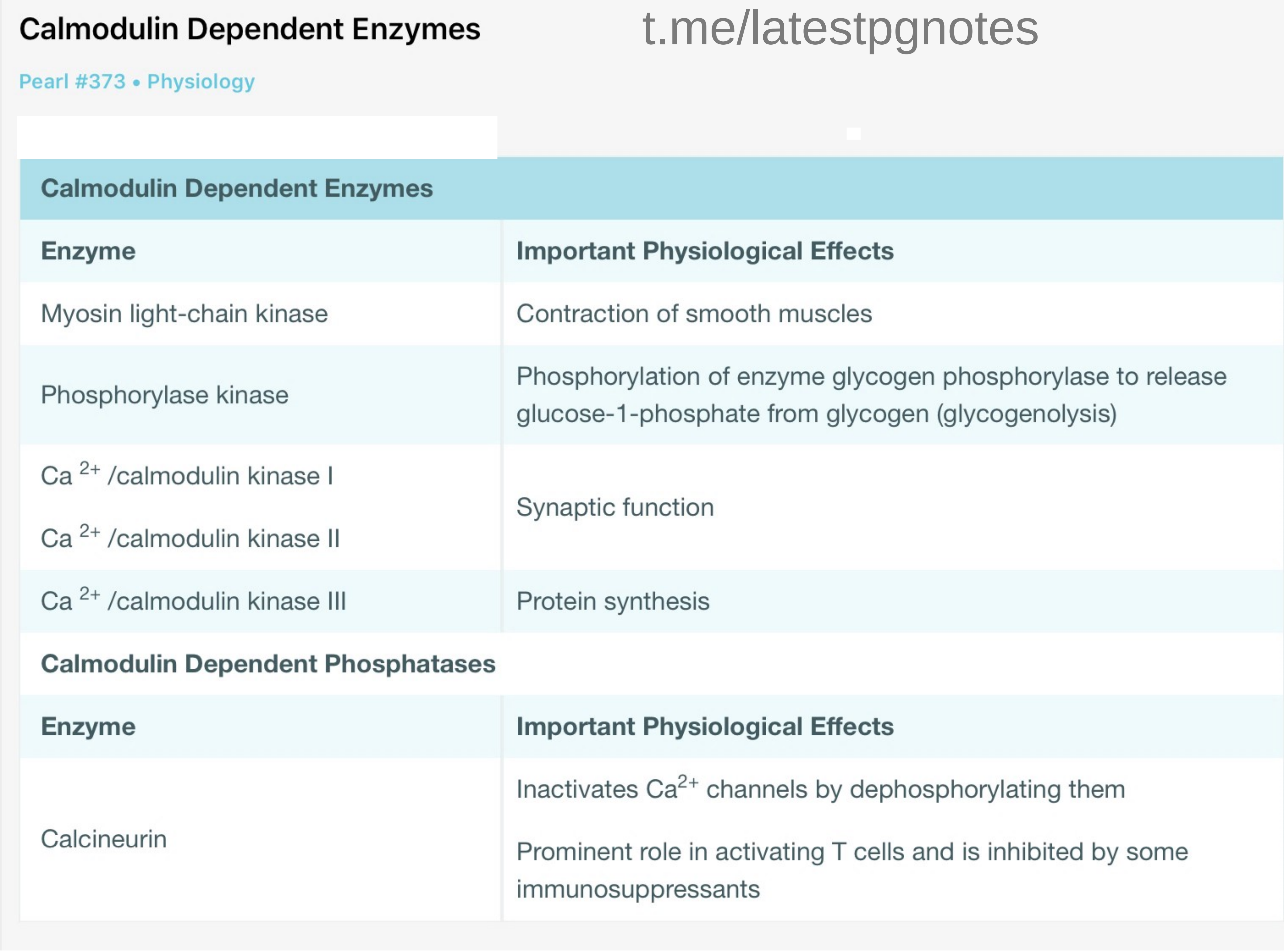
Site	Type of Mutation	Disease
Receptor (GPCR)		
Conopsins	Loss	Color blindness
Rhodopsin	Loss	Congenital night blindness; two forms of retinitis pigmentosa
V_2 vasopressin	Loss	X-linked nephrogenic diabetes insipidus
ACTH	Loss	Familial glucocorticoid deficiency
TSH	Loss	Familial hypothyroidism
Thromboxane A2	Loss	Congenital bleeding
Endothelin B	Loss	Hirschsprung disease
LH	Gain	Familial male precocious puberty
TSH	Gain	Familial nonautoimmune hyperthyroidism
Ca^{2+}	Gain	Familial hypercalciuric hypocalcemia
G protein		
G_s α	Loss	Pseudohypopara thyroidism type 1a
G_s α	Gain/loss	Testotoxicosis
G_s α	Gain (mosaic)	McCune-Albright syndrome
G_s α	Gain	Somatotroph adenomas with acromegaly
G_i α	Gain	Ovarian and adrenocortical tumors



Calmodulin Dependent Enzymes

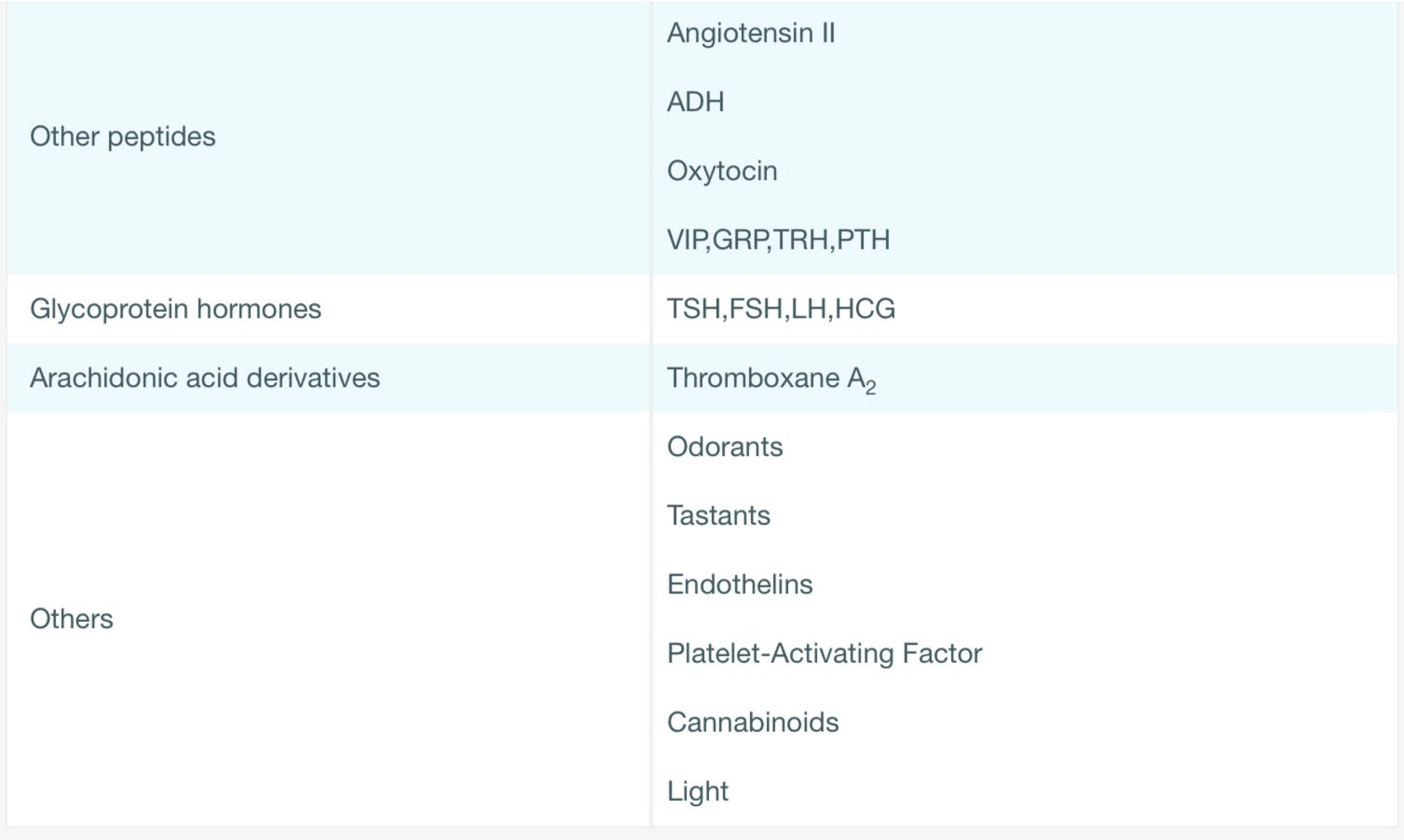
Pearl #373 • Physiology

Calmodulin Dependent Enzymes	
Enzyme	**Important Physiological Effects**
Myosin light-chain kinase	Contraction of smooth muscles
Phosphorylase kinase	Phosphorylation of enzyme glycogen phosphorylase to release glucose-1-phosphate from glycogen (glycogenolysis)
Ca $^{2+}$ /calmodulin kinase I Ca $^{2+}$ /calmodulin kinase II	Synaptic function
Ca $^{2+}$ /calmodulin kinase III	Protein synthesis
Calmodulin Dependent Phosphatases	
Enzyme	**Important Physiological Effects**
Calcineurin	Inactivates Ca^{2+} channels by dephosphorylating them Prominent role in activating T cells and is inhibited by some immunosuppressants

Ligands for G-Protein Coupled Receptors

Pearl #372 • Physiology

Class	Ligand
Neurotransmitters	Epinephrine
	Norepinephrine
	Dopamine
	Serotonin (5-Hydroxytryptamine)
	Histamine
	Acetylcholine
	Adenosine
	Opioids
Tachykinins	Substance P
	Neurokinin A
	Neuropeptide K
Other peptides	Angiotensin II
	ADH
	Oxytocin
	VIP,GRP,TRH,PTH



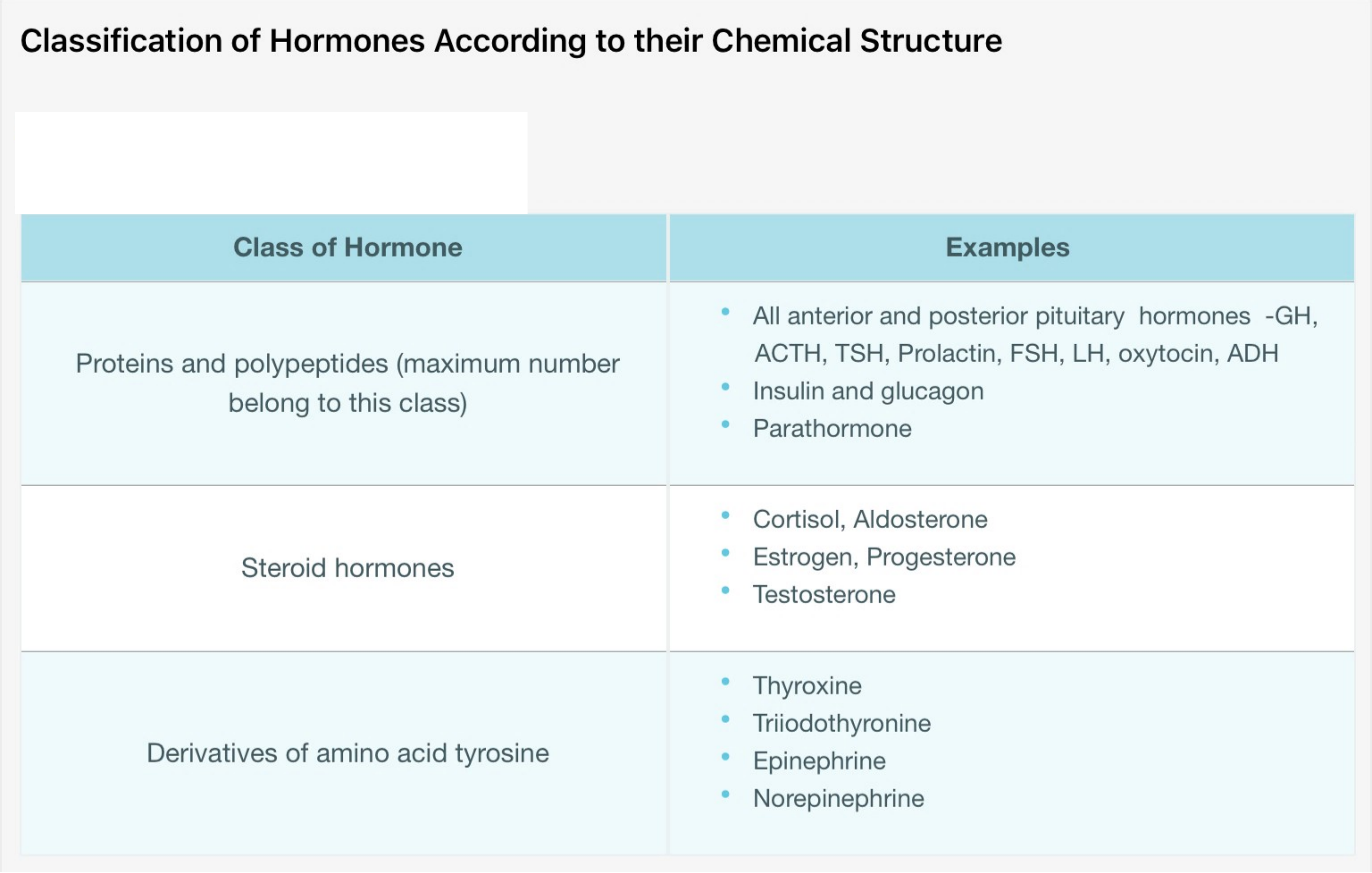
Other peptides	Angiotensin II ADH Oxytocin VIP,GRP,TRH,PTH
Glycoprotein hormones	TSH,FSH,LH,HCG
Arachidonic acid derivatives	Thromboxane A_2
Others	Odorants Tastants Endothelins Platelet-Activating Factor Cannabinoids Light

Classification of Hormones by Mechanism of Action

Pearl #371 • Physiology

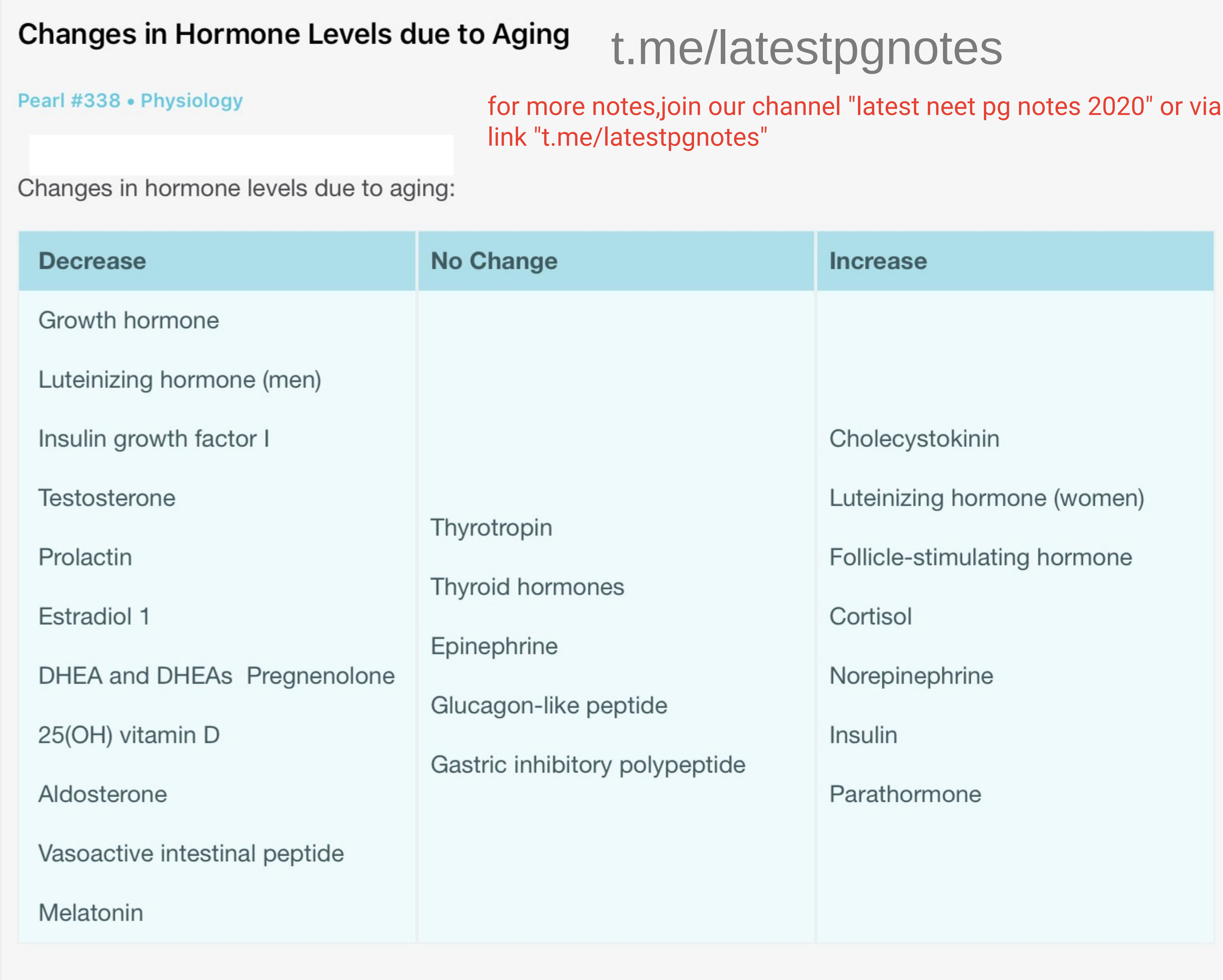
A: Hormones that bind to intracellular receptors (lipophilic, readily penetrate the cell membrane)	
Hormones that bind to cytoplasmic receptors	Androgens Estrogen, Progesterone Glucocorticoids, Mineralocorticoids
Hormones that bind to nuclear receptors	Thyroid hormones (T_3, T_4) Estrogen, Progesterone Retinoic acid Calcitriol (Vitamin D3)
B: Hormones that bind to cell surface receptors (hydrophilic)	
The second messenger is cAMP(Gs)	CRH, ACTH, Catecholamines (β_1 & β_2 receptors) Parathyroid Hormone (PTH), TSH, calcitonin FSH, LH, HCG MSH ADH (V_2 receptors) Glucagon Somatostatin Secretin
By decreasing second messanger cAMP(Gi)	alpha2 adrenergic ACh(M2,M4) Somatostatin

The second messenger is cGMP(Guanylyl Cyclase)	Atrial natriuretic factor (ANF)
	Nitric oxide (NO)
The second messenger is IP_3-DAG (Phopholipase C)(Gq)	Acetyl choline (Muscarinic)
	Angiotensin II
	ADH (V_1 receptor)
	Catecholamines α_1 receptor
	Cholecystokinin
	Gastrin
	GnRH, GHRH,TRH
	Oxytocin
	Substance P
The second messenger is kinase or phosphatase cascade	Erythropoietin
	Growth hormone
	Insulin, IGF-1
	Leptin
	Adiponectin
	Prolactin
	Platelet Derived Growth Factor (PDGF)
	Epidermal growth factor
	Fibroblast Growth Factor
	Nerve Growth Factor
	VEGF



Classification of Hormones According to their Chemical Structure

Class of Hormone	Examples
Proteins and polypeptides (maximum number belong to this class)	• All anterior and posterior pituitary hormones -GH, ACTH, TSH, Prolactin, FSH, LH, oxytocin, ADH • Insulin and glucagon • Parathormone
Steroid hormones	• Cortisol, Aldosterone • Estrogen, Progesterone • Testosterone
Derivatives of amino acid tyrosine	• Thyroxine • Triiodothyronine • Epinephrine • Norepinephrine



Changes in Hormone Levels due to Aging

Pearl #338 • Physiology

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Changes in hormone levels due to aging:

Decrease	No Change	Increase
Growth hormone Luteinizing hormone (men) Insulin growth factor I Testosterone Prolactin Estradiol 1 DHEA and DHEAs Pregnenolone 25(OH) vitamin D Aldosterone Vasoactive intestinal peptide Melatonin	Thyrotropin Thyroid hormones Epinephrine Glucagon-like peptide Gastric inhibitory polypeptide	Cholecystokinin Luteinizing hormone (women) Follicle-stimulating hormone Cortisol Norepinephrine Insulin Parathormone

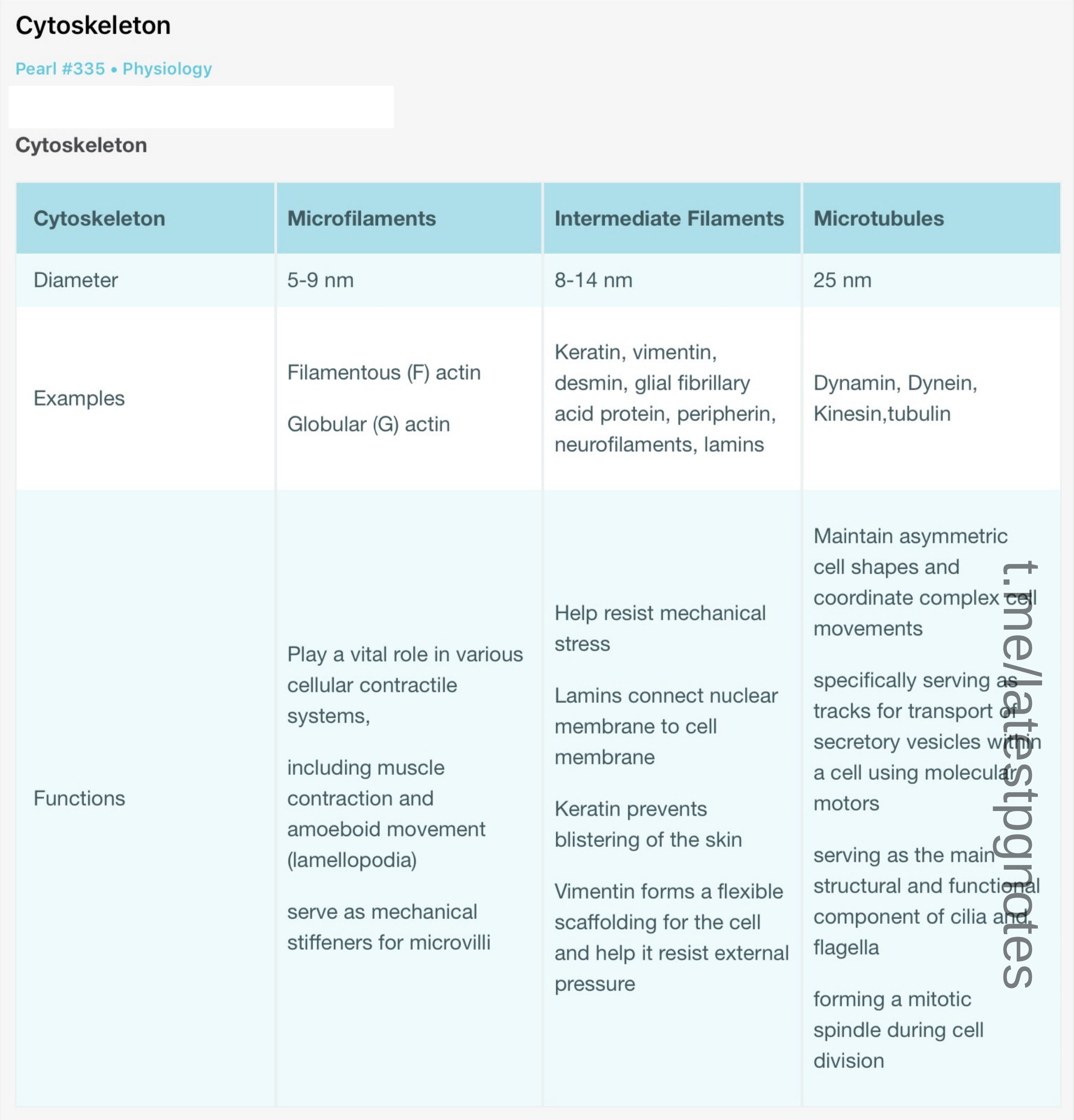
Physiological Changes in Aging

Pearl #337 • Physiology

Physiological changes in aging:

Systems	Changes
General Changes	↓ BMR ↓ Lean body mass, ↑ adiposity
Skin	Thinning of epidermis and dermis due to ↓ in elastin and collagen melanocytes→↓ photoprotection Net effect- Wrinkling of skin active melanocytes in hair follicles→ graying of hair nail growth
Skeletal muscle	Steady ↓ in skeletal muscle mass (Sarcopenia)
Bone	Bone resorption exceeds formation →Bone loss → Osteoporosis
Synovial Joint	Thinning and altered mechanical features of articular cartilage → Osteoarthritis
Central nervous system	**Sensory**- deteriorates with age Hearing loss particularly for high frequency Vision- deteriorates due to presbyopia, cataract, glaucoma, macular degeneration Reduction in taste and olfactory sensation **Motor**- Slowing of reaction time (time between stimulus and motor response), slowing of central processing **Cognitive functions** decline

Cardiovascular system	arterial distensibility,↓ arterial compliance→↑SBP,↓DBP→↑Pulse pressure ↓Arterial compliance→↑afterload EDV no change, thus, preload not affected Blunting of baroreceptor reflex→postural hypotension
Respiratory System	Decreased strength and endurance of respiratory muscles due to atrophy→ ↓ in both static and forced expiratory volume Small airways tend to collapse due to degeneration of collagen and elastin
Exercise	↓ Vo_{2max}
Renals	↓GFR linearly with age ↓ clearance ↓ in capacity and compliance of bladder Prostrate enlargement
Gastrointestinal tract	↓ in exocrine gland secretion (eg- ↓ gastric acidity) ↓ in colonic motility
Endocrines	↓ IGF-1, DHEA, TSH ↑PTH Menopause, andropause

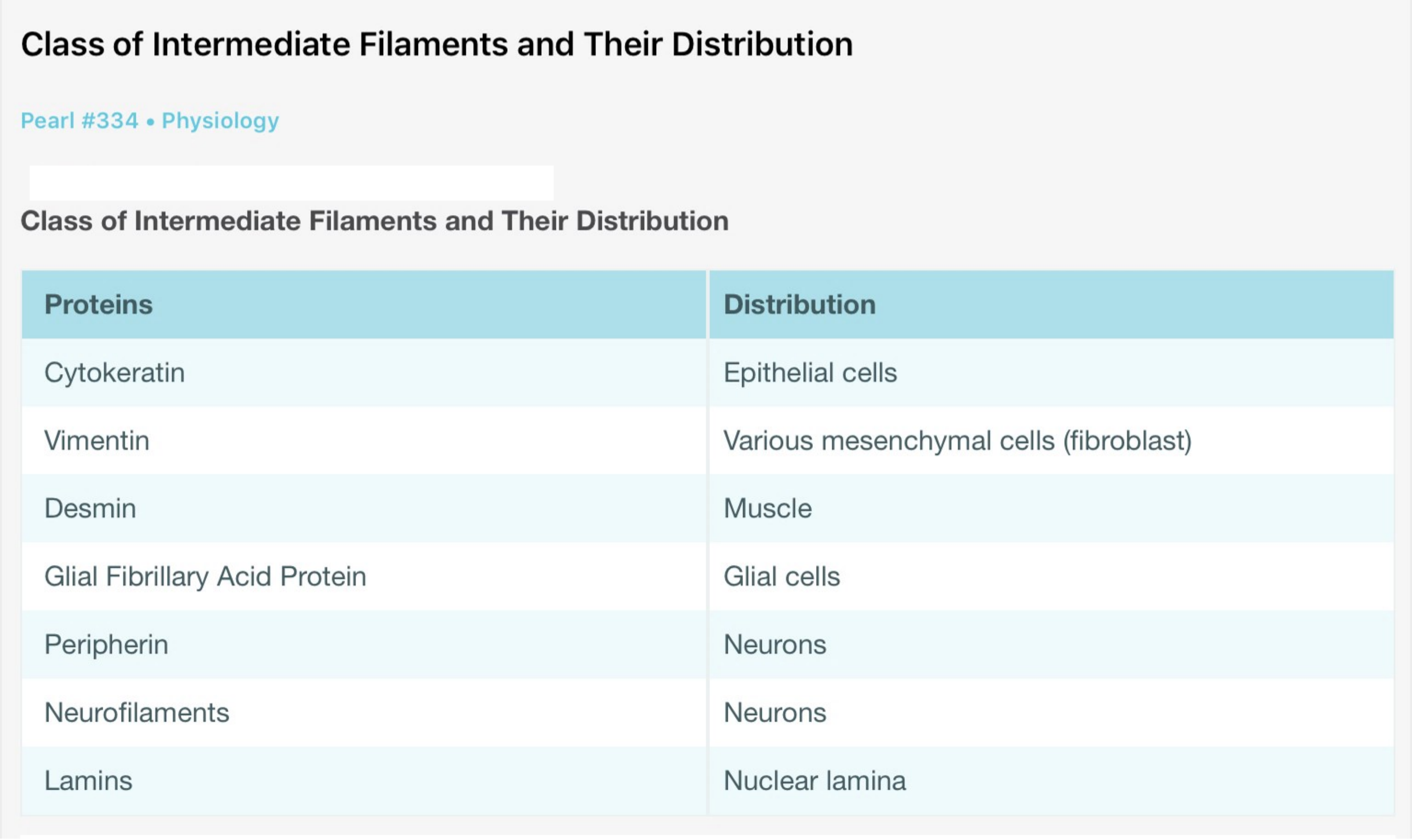


Cytoskeleton

Pearl #335 • Physiology

Cytoskeleton

Cytoskeleton	Microfilaments	Intermediate Filaments	Microtubules
Diameter	5-9 nm	8-14 nm	25 nm
Examples	Filamentous (F) actin Globular (G) actin	Keratin, vimentin, desmin, glial fibrillary acid protein, peripherin, neurofilaments, lamins	Dynamin, Dynein, Kinesin,tubulin
Functions	Play a vital role in various cellular contractile systems, including muscle contraction and amoeboid movement (lamellopodia) serve as mechanical stiffeners for microvilli	Help resist mechanical stress Lamins connect nuclear membrane to cell membrane Keratin prevents blistering of the skin Vimentin forms a flexible scaffolding for the cell and help it resist external pressure	Maintain asymmetric cell shapes and coordinate complex cell movements specifically serving as tracks for transport of secretory vesicles within a cell using molecular motors serving as the main structural and functional component of cilia and flagella forming a mitotic spindle during cell division



Class of Intermediate Filaments and Their Distribution

Pearl #334 • Physiology

Class of Intermediate Filaments and Their Distribution

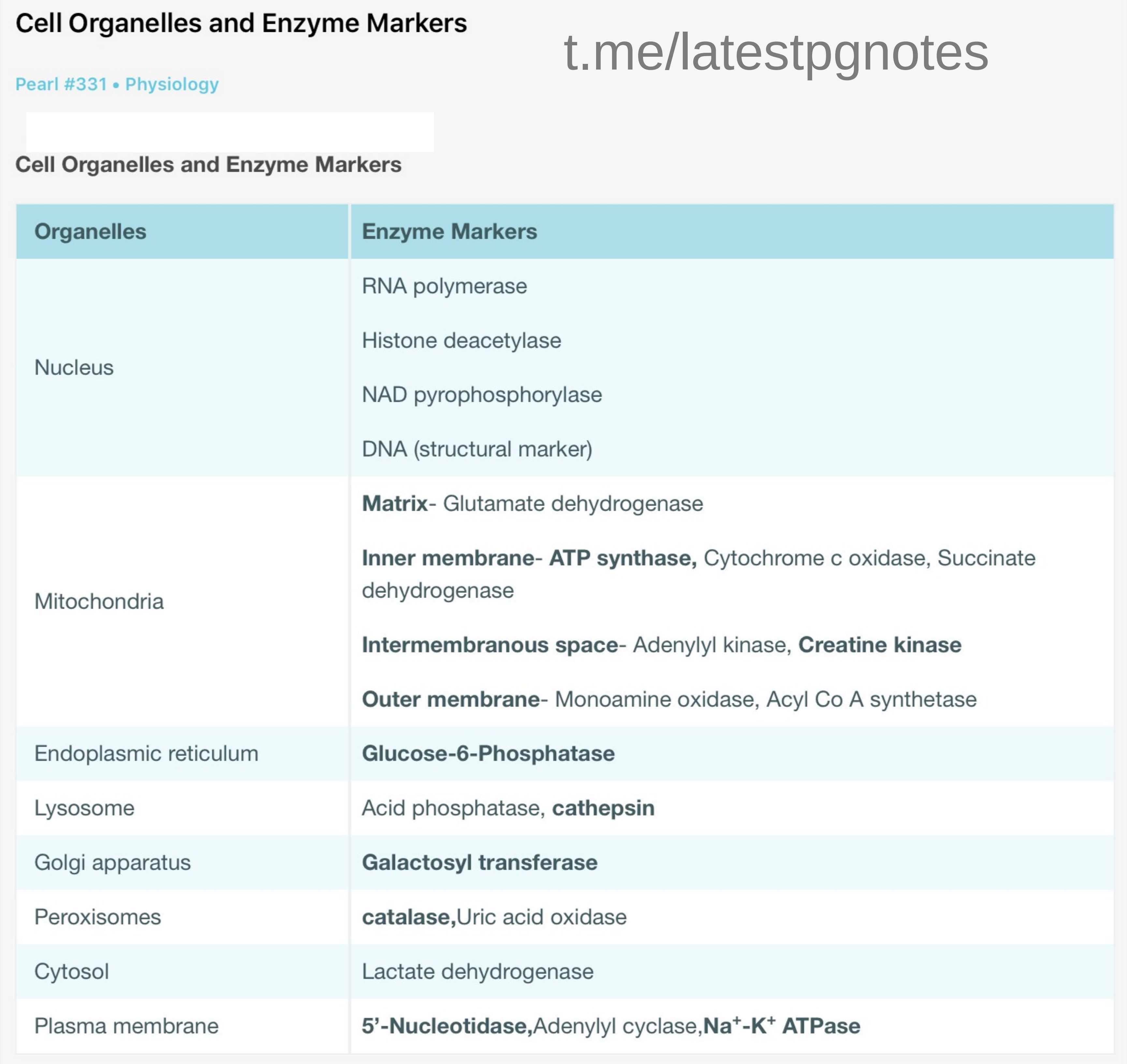
Proteins	Distribution
Cytokeratin	Epithelial cells
Vimentin	Various mesenchymal cells (fibroblast)
Desmin	Muscle
Glial Fibrillary Acid Protein	Glial cells
Peripherin	Neurons
Neurofilaments	Neurons
Lamins	Nuclear lamina

Principal Serum Enzymes used in Clinical Diagnosis

Pearl #332 • Physiology

Principal Serum Enzymes used in Clinical Diagnosis

Serum enzymes	Major diagnostic use
Aminotransferases Aspartate aminotransferase (AST, or SGOT) Alanine aminotransferase (ALT, or SGPT)	Myocardial infarction Viral hepatitis
Amylase, Lipase	Acute pancreatitis
Ceruloplasmin	Hepatolenticular degeneration (Wilson's disease)
Creatine kinase	Muscle disorders and myocardial infarction
ɣ-Glutamyl transpeptidase	Various liver diseases
Lactate dehydrogenase (isozymes)	Myocardial infarction
Acid Phosphatase	Metastatic carcinoma of the Prostate
Alkaline Phosphatase (isozymes)	Various bone disorders, obstructive liver diseases

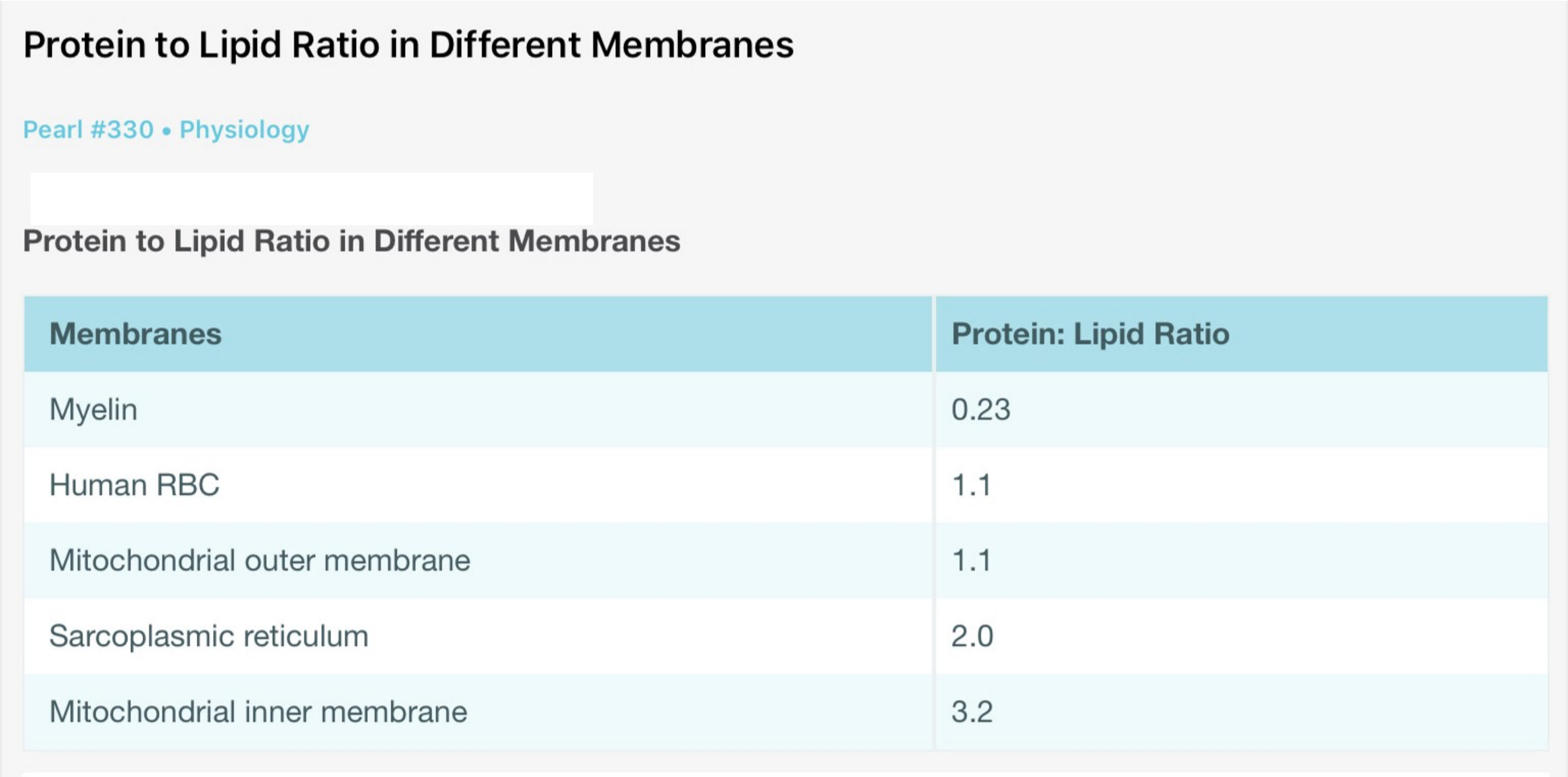


Cell Organelles and Enzyme Markers

Pearl #331 • Physiology

Cell Organelles and Enzyme Markers

Organelles	Enzyme Markers
Nucleus	RNA polymerase Histone deacetylase NAD pyrophosphorylase DNA (structural marker)
Mitochondria	**Matrix**- Glutamate dehydrogenase **Inner membrane**- **ATP synthase,** Cytochrome c oxidase, Succinate dehydrogenase **Intermembranous space**- Adenylyl kinase, **Creatine kinase** **Outer membrane**- Monoamine oxidase, Acyl Co A synthetase
Endoplasmic reticulum	**Glucose-6-Phosphatase**
Lysosome	Acid phosphatase, **cathepsin**
Golgi apparatus	**Galactosyl transferase**
Peroxisomes	**catalase,**Uric acid oxidase
Cytosol	Lactate dehydrogenase
Plasma membrane	**5'-Nucleotidase,**Adenylyl cyclase,**Na$^+$-K$^+$ ATPase**

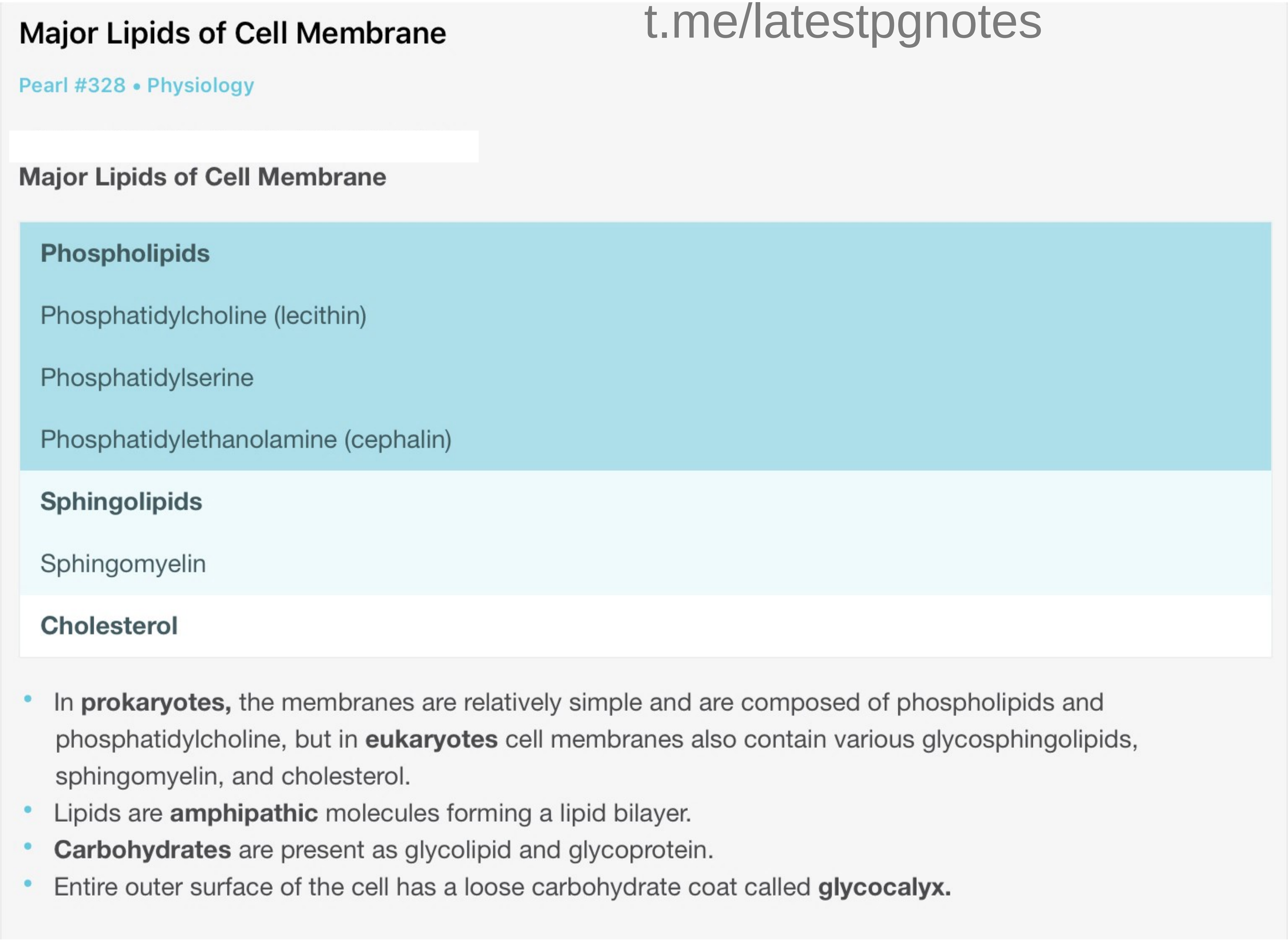


Protein to Lipid Ratio in Different Membranes

Pearl #330 • Physiology

Protein to Lipid Ratio in Different Membranes

Membranes	Protein: Lipid Ratio
Myelin	0.23
Human RBC	1.1
Mitochondrial outer membrane	1.1
Sarcoplasmic reticulum	2.0
Mitochondrial inner membrane	3.2



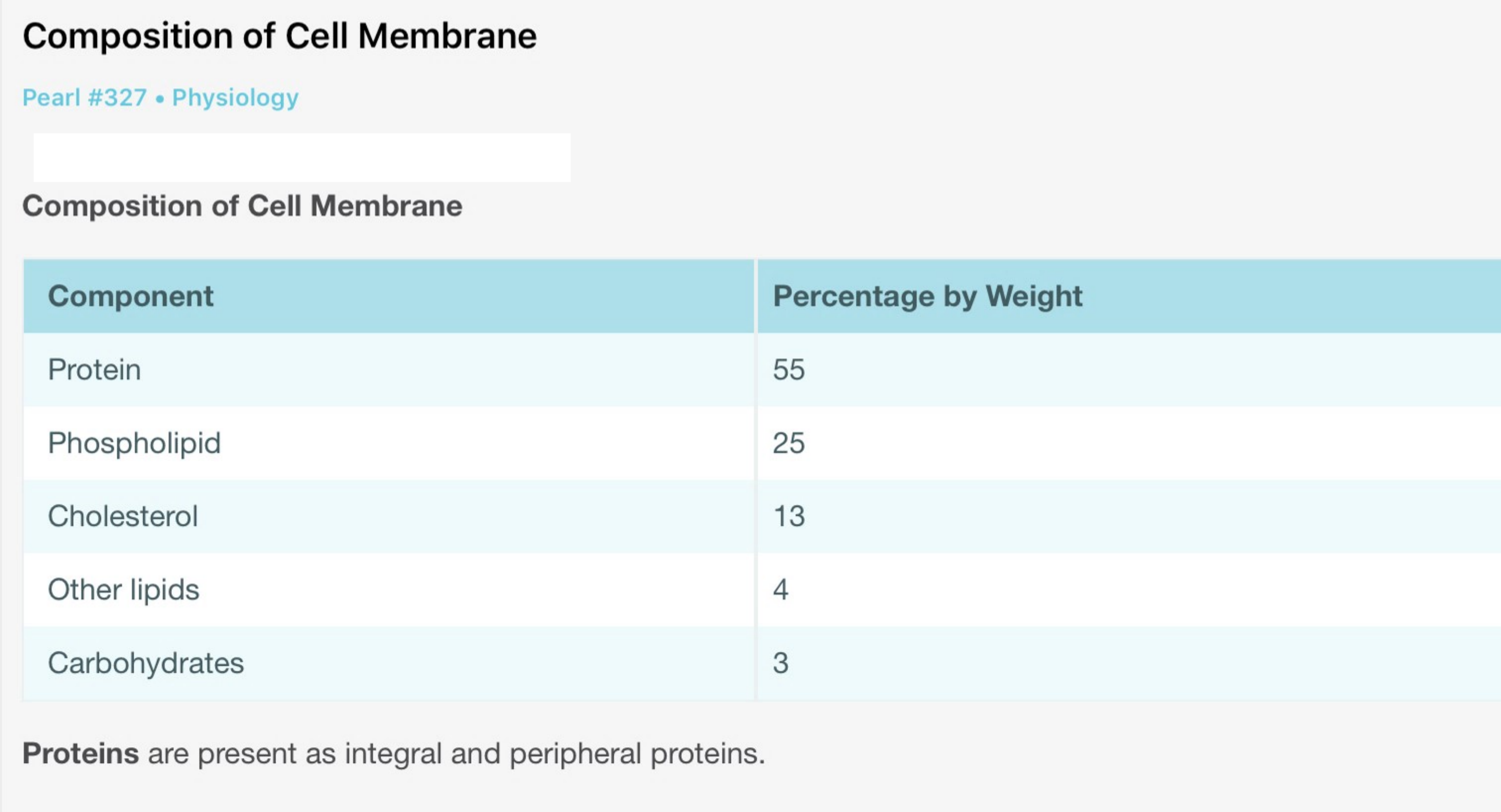
Major Lipids of Cell Membrane

Pearl #328 • Physiology

Major Lipids of Cell Membrane

Phospholipids
Phosphatidylcholine (lecithin)
Phosphatidylserine
Phosphatidylethanolamine (cephalin)
Sphingolipids
Sphingomyelin
Cholesterol

- In **prokaryotes,** the membranes are relatively simple and are composed of phospholipids and phosphatidylcholine, but in **eukaryotes** cell membranes also contain various glycosphingolipids, sphingomyelin, and cholesterol.
- Lipids are **amphipathic** molecules forming a lipid bilayer.
- **Carbohydrates** are present as glycolipid and glycoprotein.
- Entire outer surface of the cell has a loose carbohydrate coat called **glycocalyx.**



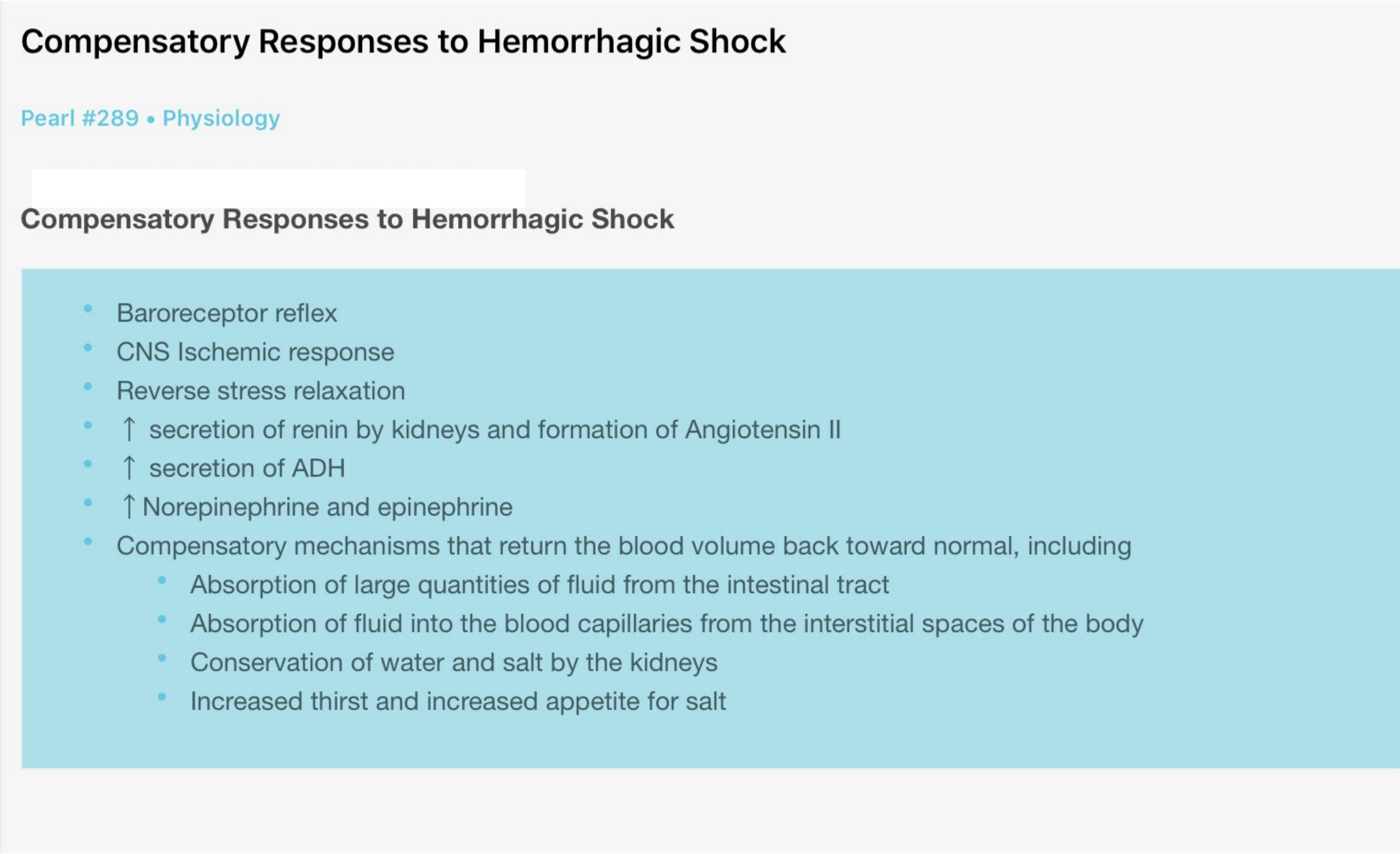
Composition of Cell Membrane

Pearl #327 • Physiology

Composition of Cell Membrane

Component	Percentage by Weight
Protein	55
Phospholipid	25
Cholesterol	13
Other lipids	4
Carbohydrates	3

Proteins are present as integral and peripheral proteins.



Compensatory Responses to Hemorrhagic Shock

Pearl #289 • Physiology

Compensatory Responses to Hemorrhagic Shock

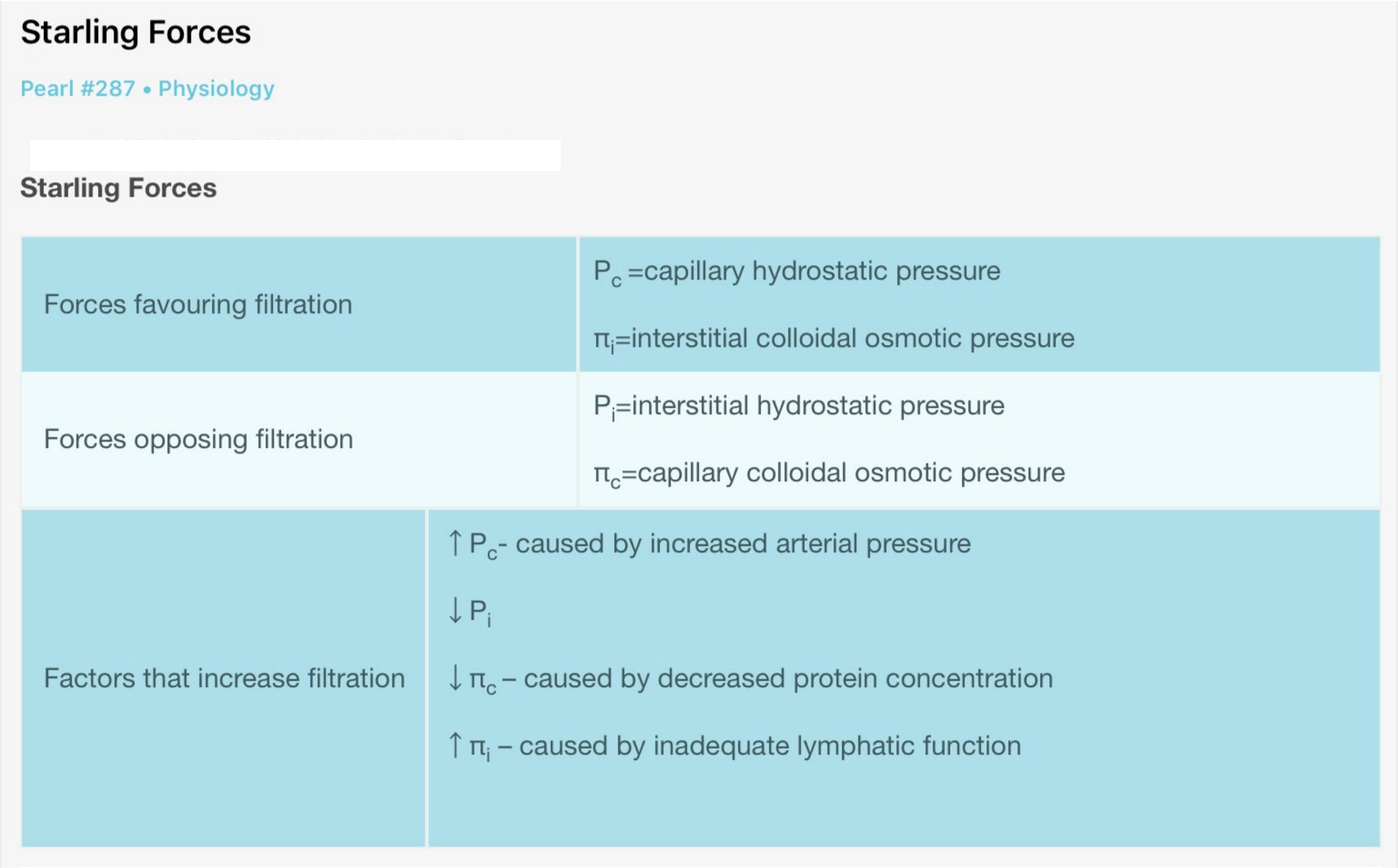
- Baroreceptor reflex
- CNS Ischemic response
- Reverse stress relaxation
- ↑ secretion of renin by kidneys and formation of Angiotensin II
- ↑ secretion of ADH
- ↑ Norepinephrine and epinephrine
- Compensatory mechanisms that return the blood volume back toward normal, including
    - Absorption of large quantities of fluid from the intestinal tract
    - Absorption of fluid into the blood capillaries from the interstitial spaces of the body
    - Conservation of water and salt by the kidneys
    - Increased thirst and increased appetite for salt

Summary of Pathogenesis of Major Findings in Congestive Heart Failure

Pearl #288 • Physiology

Summary of Pathogenesis of Major Findings in Congestive Heart Failure

Abnormality	Cause
Weakness, exercise intolerance, fatigue	Left ventricle output inadequate to perfuse muscles; especially, failure of output to rise with exercise
Ankle, sacral edema	Increased peripheral venous pressure →increased fluid transudation.
Hepatomegaly	Increased peripheral venous pressure →increased resistance to portal flow.
Pulmonary congestion	Increased pulmonary venous pressure →pulmonary venous distention and transudation of fluid into air spaces
Dyspnea on exertion	Failure of left ventricular output to rise during exercise → increased pulmonary venous pressure
Paroxysmal dyspnea, pulmonary edema	Probably a sudden failure of left heart output to keep up with the right heart output →acute rise in pulmonary venous and capillary pressure →transudation of fluid into air spaces.
Orthopnea	Normal pooling of blood in lungs in supine position added to the already congested pulmonary vascular system; increased venous return not put out by the left ventricle. (Relieved by sitting up, raising the head of the bed, lying on extra pillows.)
Cardiac dilation	Greater ventricular end-diastolic volume.



Starling Forces

Pearl #287 • Physiology

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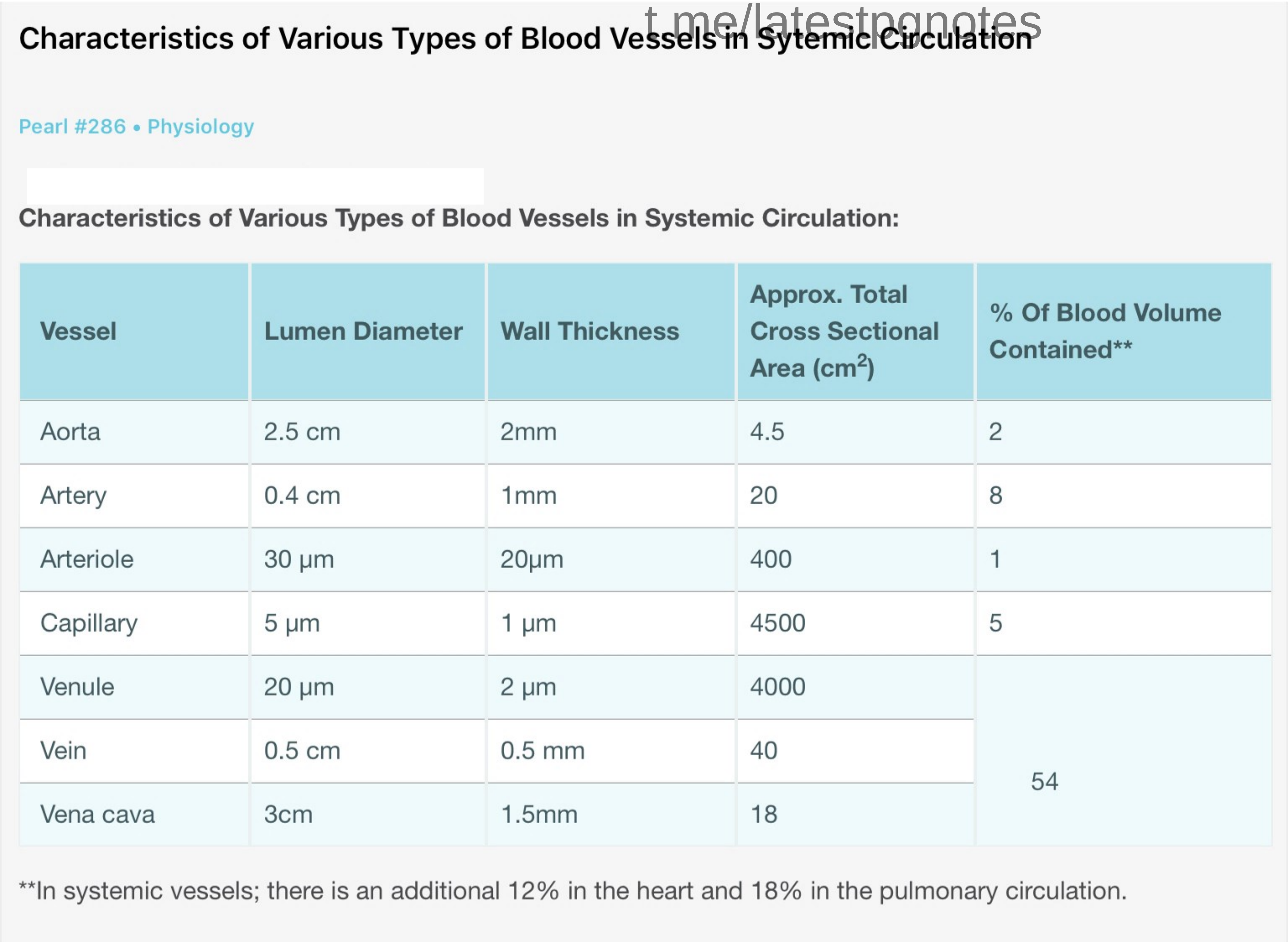
Starling Forces

Forces favouring filtration	P_c =capillary hydrostatic pressure π_i=interstitial colloidal osmotic pressure
Forces opposing filtration	P_i=interstitial hydrostatic pressure π_c=capillary colloidal osmotic pressure

Factors that increase filtration	↑ P_c- caused by increased arterial pressure ↓ P_i ↓ π_c – caused by decreased protein concentration ↑ π_i – caused by inadequate lymphatic function



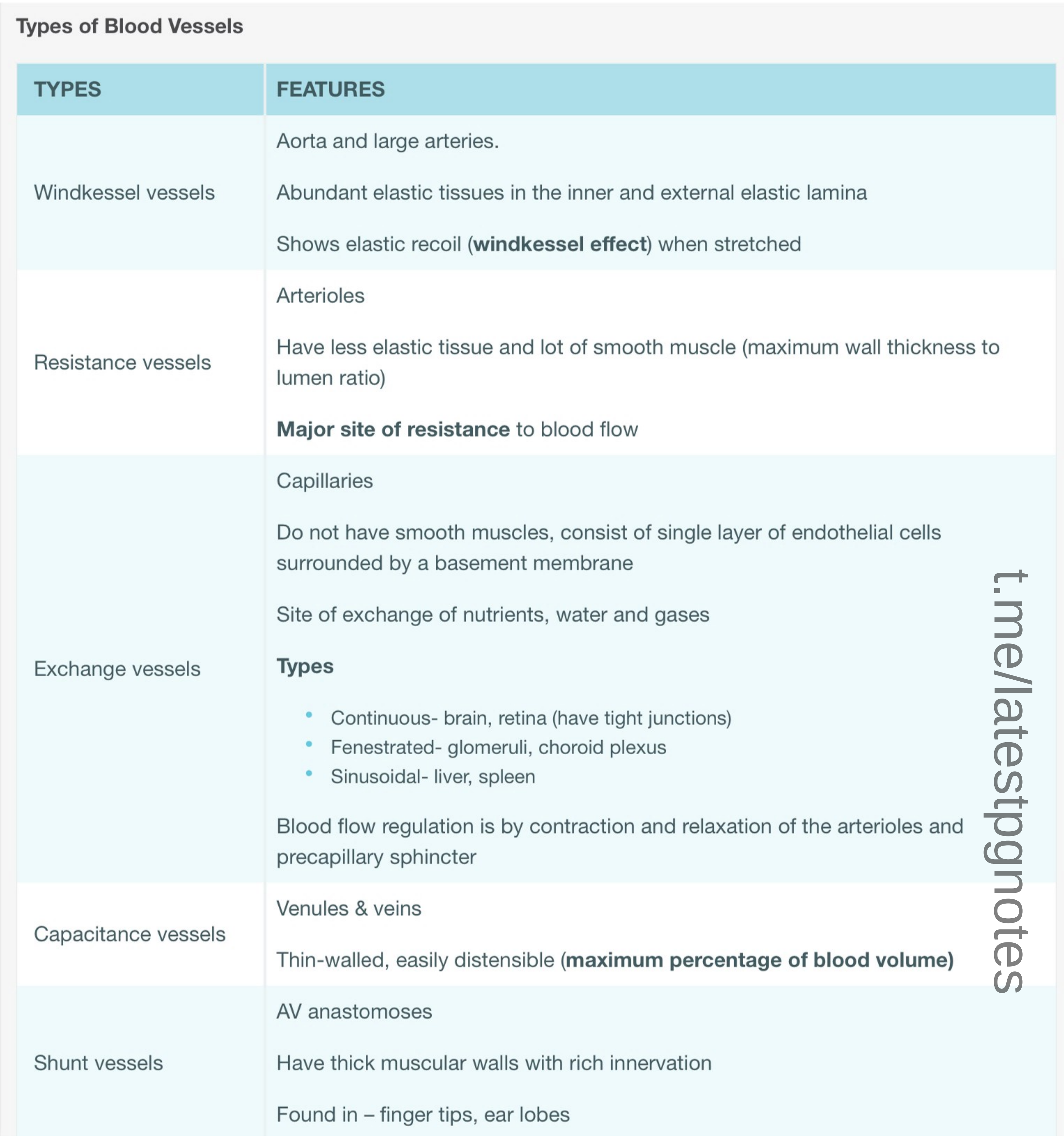
Characteristics of Various Types of Blood Vessels in Sytemic Circulation

Pearl #286 • Physiology

Characteristics of Various Types of Blood Vessels in Systemic Circulation:

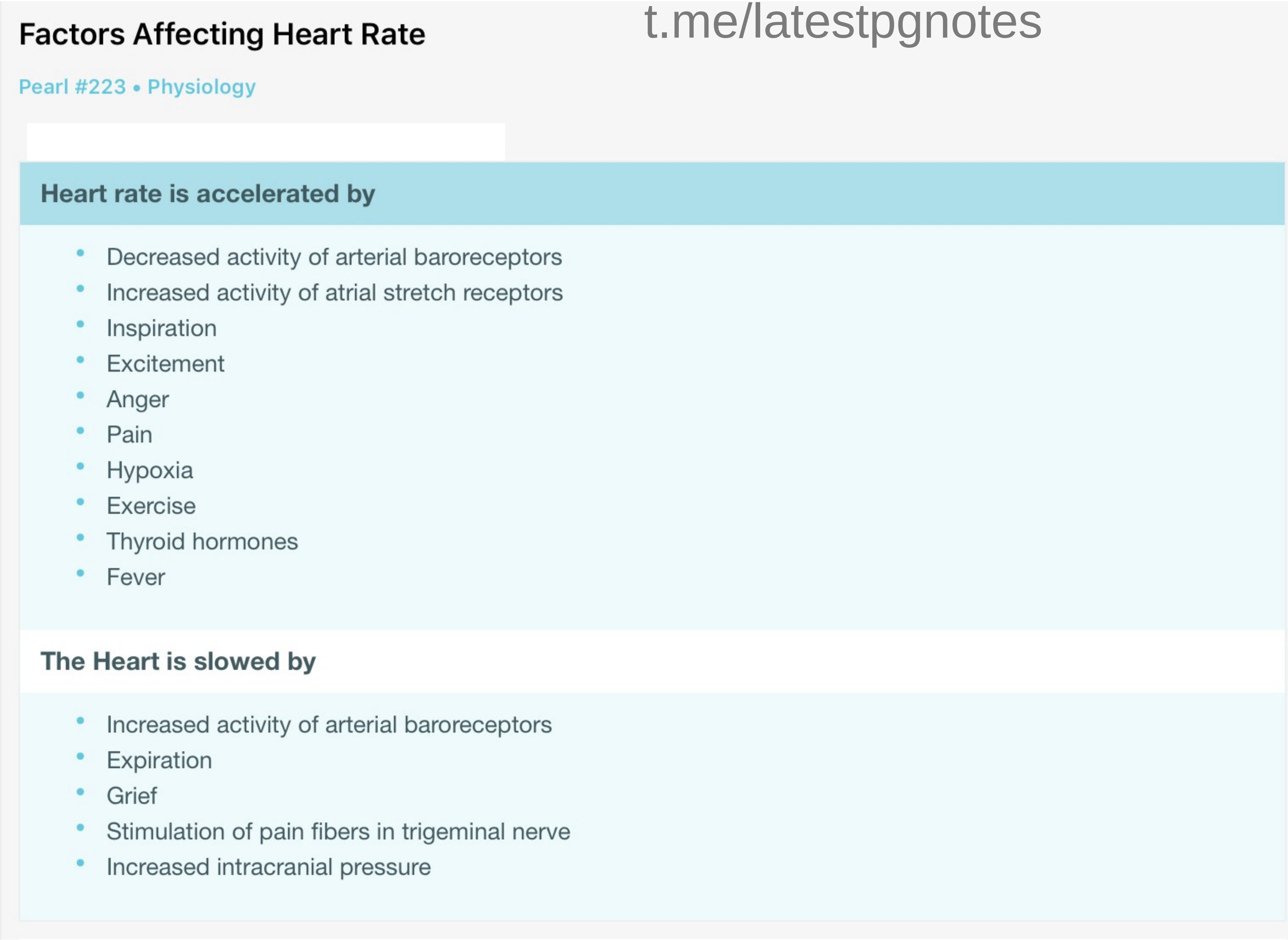
Vessel	Lumen Diameter	Wall Thickness	Approx. Total Cross Sectional Area (cm^2)	% Of Blood Volume Contained**
Aorta	2.5 cm	2mm	4.5	2
Artery	0.4 cm	1mm	20	8
Arteriole	30 µm	20µm	400	1
Capillary	5 µm	1 µm	4500	5
Venule	20 µm	2 µm	4000	54
Vein	0.5 cm	0.5 mm	40	
Vena cava	3cm	1.5mm	18	

**In systemic vessels; there is an additional 12% in the heart and 18% in the pulmonary circulation.



Types of Blood Vessels

TYPES	FEATURES
Windkessel vessels	Aorta and large arteries. Abundant elastic tissues in the inner and external elastic lamina Shows elastic recoil (**windkessel effect**) when stretched
Resistance vessels	Arterioles Have less elastic tissue and lot of smooth muscle (maximum wall thickness to lumen ratio) **Major site of resistance** to blood flow
Exchange vessels	Capillaries Do not have smooth muscles, consist of single layer of endothelial cells surrounded by a basement membrane Site of exchange of nutrients, water and gases **Types** • Continuous- brain, retina (have tight junctions) • Fenestrated- glomeruli, choroid plexus • Sinusoidal- liver, spleen Blood flow regulation is by contraction and relaxation of the arterioles and precapillary sphincter
Capacitance vessels	Venules & veins Thin-walled, easily distensible (**maximum percentage of blood volume)**
Shunt vessels	AV anastomoses Have thick muscular walls with rich innervation Found in – finger tips, ear lobes



Factors Affecting Heart Rate

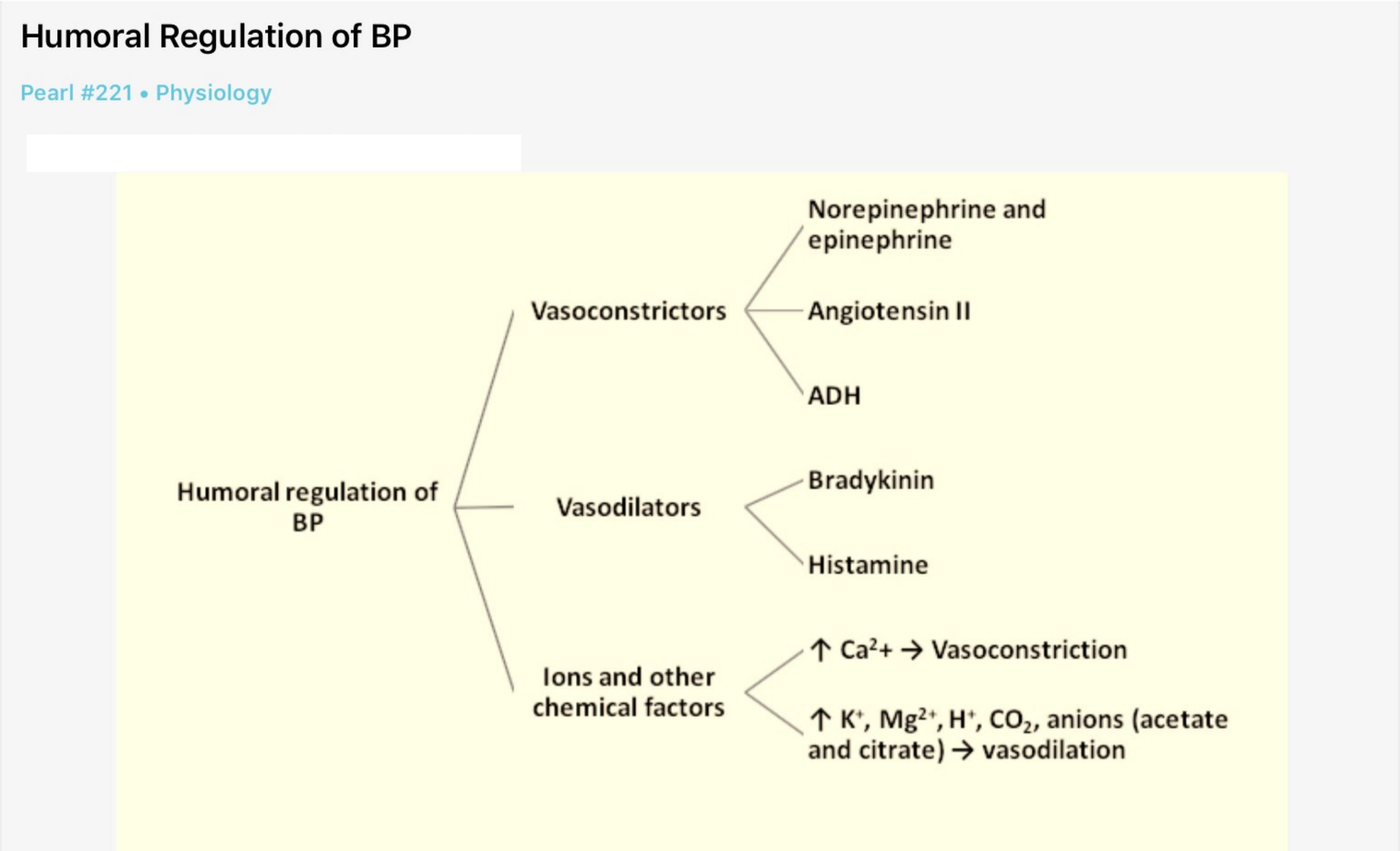
Pearl #223 • Physiology

Heart rate is accelerated by

- Decreased activity of arterial baroreceptors
- Increased activity of atrial stretch receptors
- Inspiration
- Excitement
- Anger
- Pain
- Hypoxia
- Exercise
- Thyroid hormones
- Fever

The Heart is slowed by

- Increased activity of arterial baroreceptors
- Expiration
- Grief
- Stimulation of pain fibers in trigeminal nerve
- Increased intracranial pressure



Humoral Regulation of BP

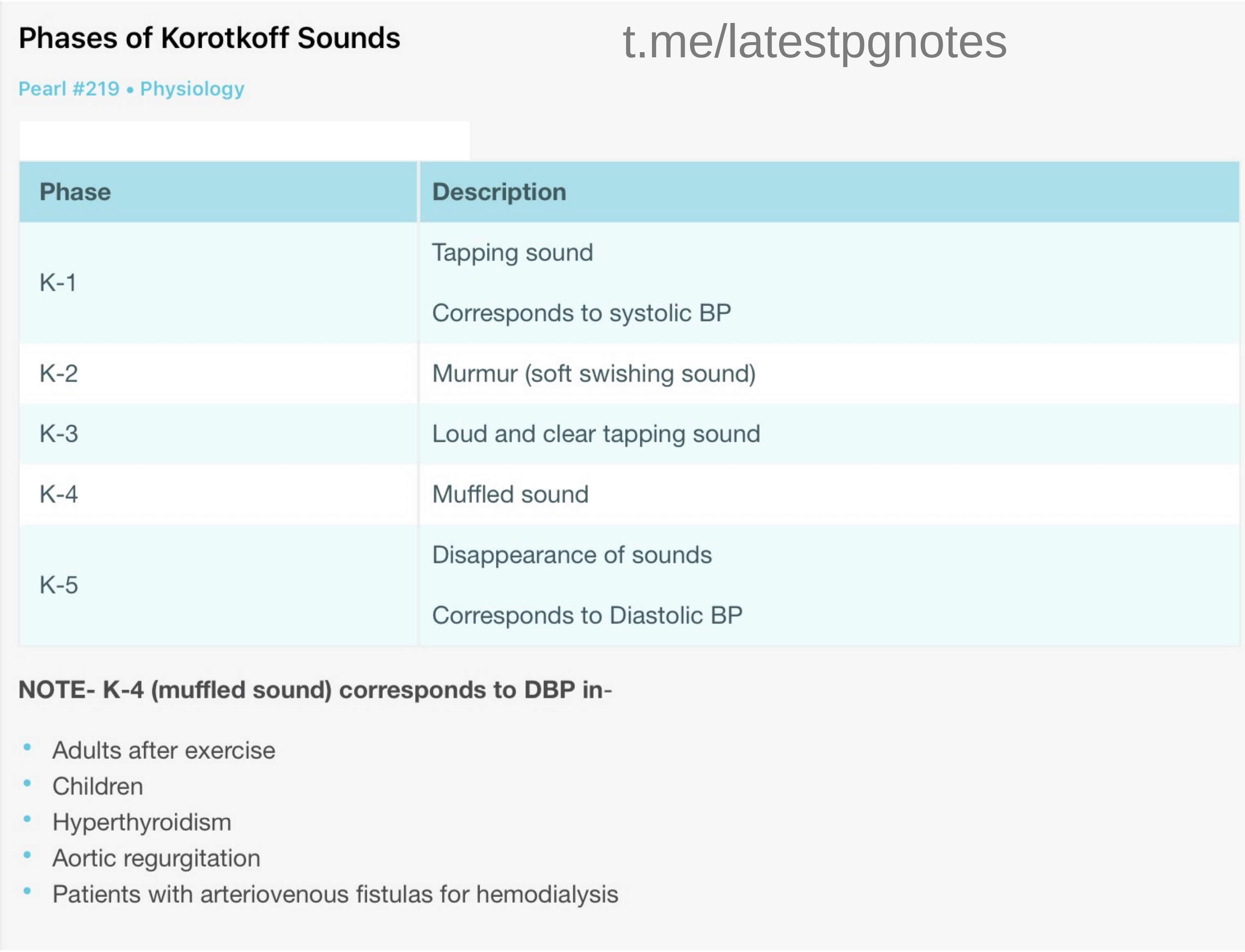
Pearl #221 • Physiology

- Humoral regulation of BP
  - Vasoconstrictors
    - Norepinephrine and epinephrine
    - Angiotensin II
    - ADH
  - Vasodilators
    - Bradykinin
    - Histamine
  - Ions and other chemical factors
    - ↑ $Ca^{2}+$ → Vasoconstriction
    - ↑ K^{+}, Mg^{2+}, H^{+}, CO_2, anions (acetate and citrate) → vasodilation

Normal Value for Hemodynamic Parameters

Pearl #220 • Physiology

Parameter		Pressure (mmHg)
Arterial BP	Systolic	90-140
	Diastolic	60-90
	Mean Arterial Pressure (MAP)	70-105
Right ventricle	Systolic	15-25
	Diastolic	0-8
Pulmonary artery	Systolic	15-25
	Diastolic	8-15
	Mean	10-20
Pulmonary capillary wedge pressure	Mean	6-12
Left atrium	Mean	6-12
Right atrium (central venous pressure)	Mean	2-6



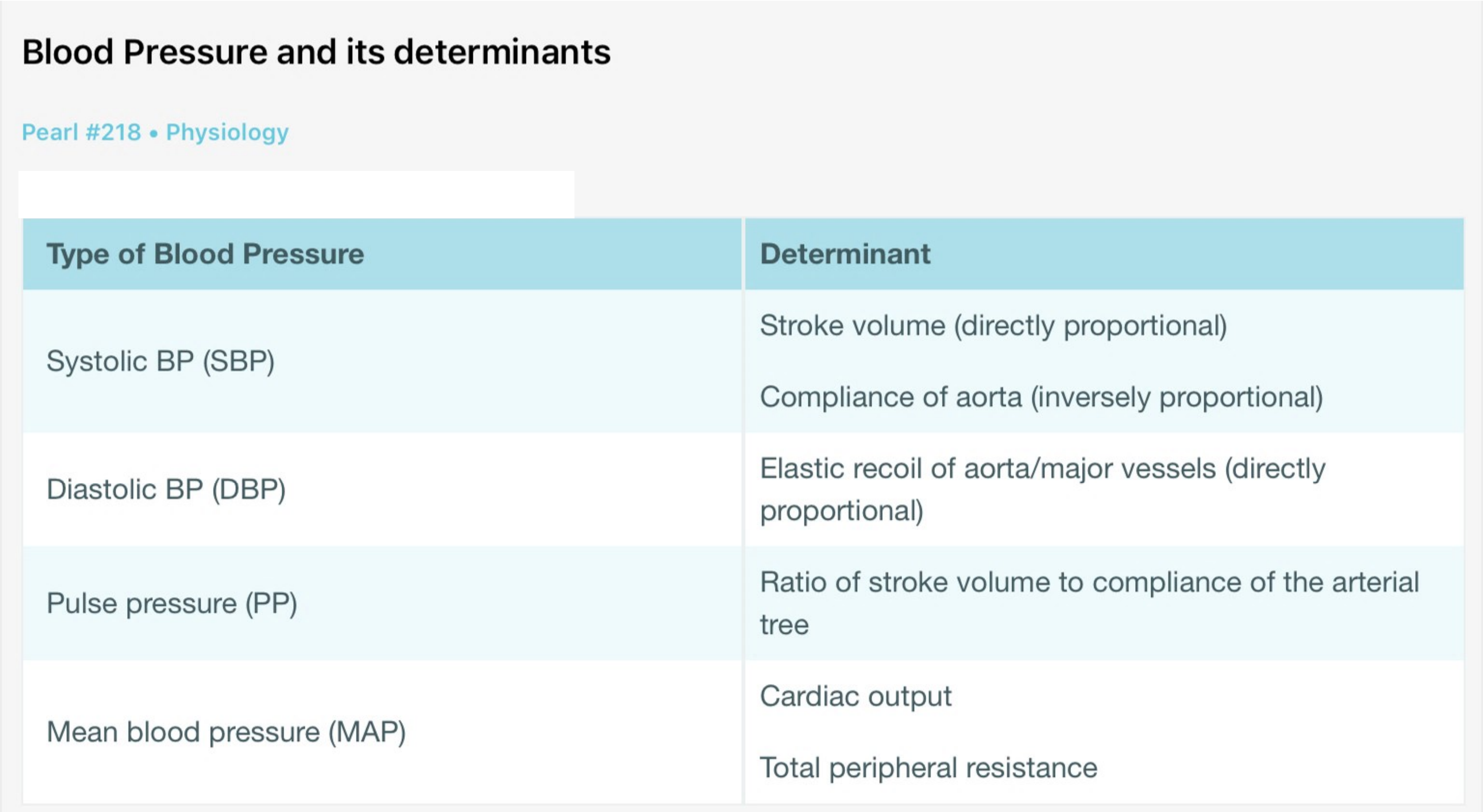
Phases of Korotkoff Sounds

Pearl #219 • Physiology

Phase	Description
K-1	Tapping sound Corresponds to systolic BP
K-2	Murmur (soft swishing sound)
K-3	Loud and clear tapping sound
K-4	Muffled sound
K-5	Disappearance of sounds Corresponds to Diastolic BP

NOTE- K-4 (muffled sound) corresponds to DBP in-

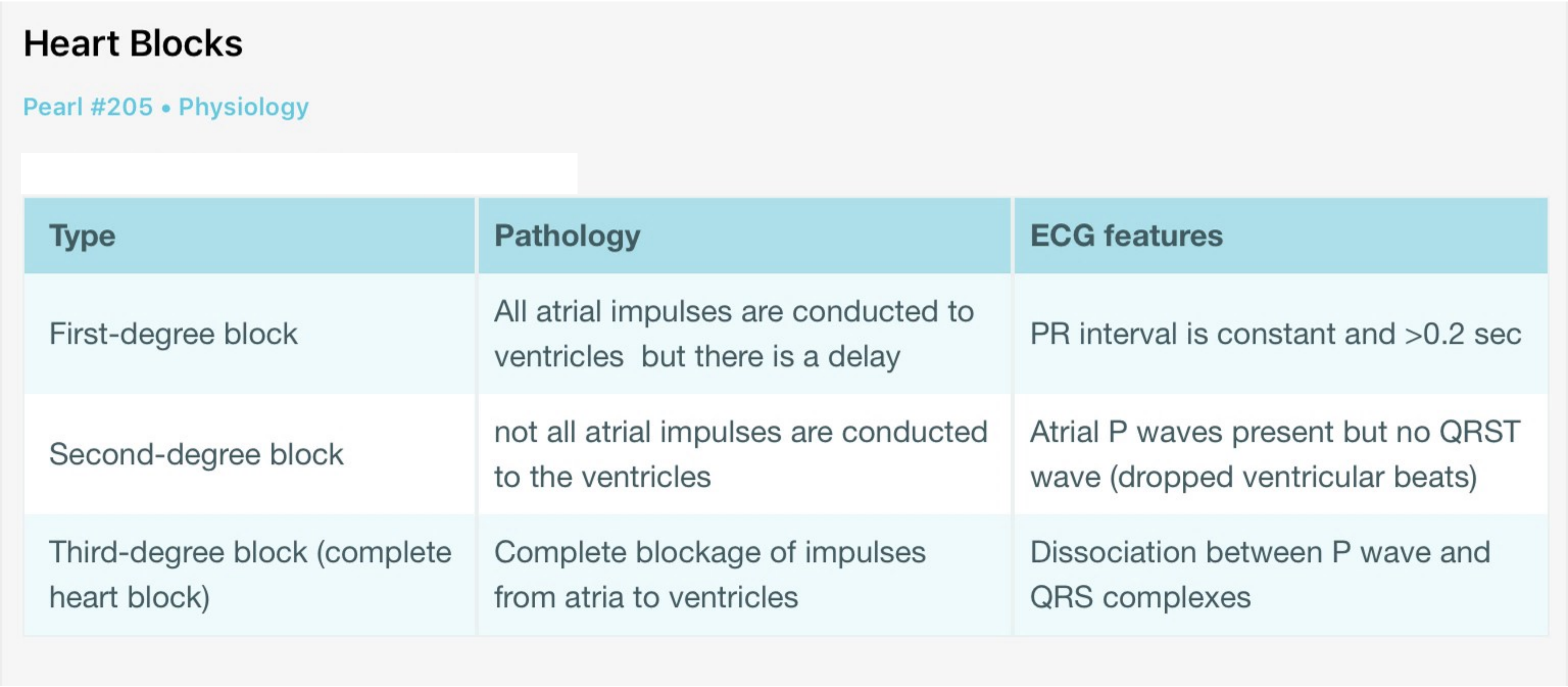
- Adults after exercise
- Children
- Hyperthyroidism
- Aortic regurgitation
- Patients with arteriovenous fistulas for hemodialysis



Blood Pressure and its determinants

Pearl #218 • Physiology

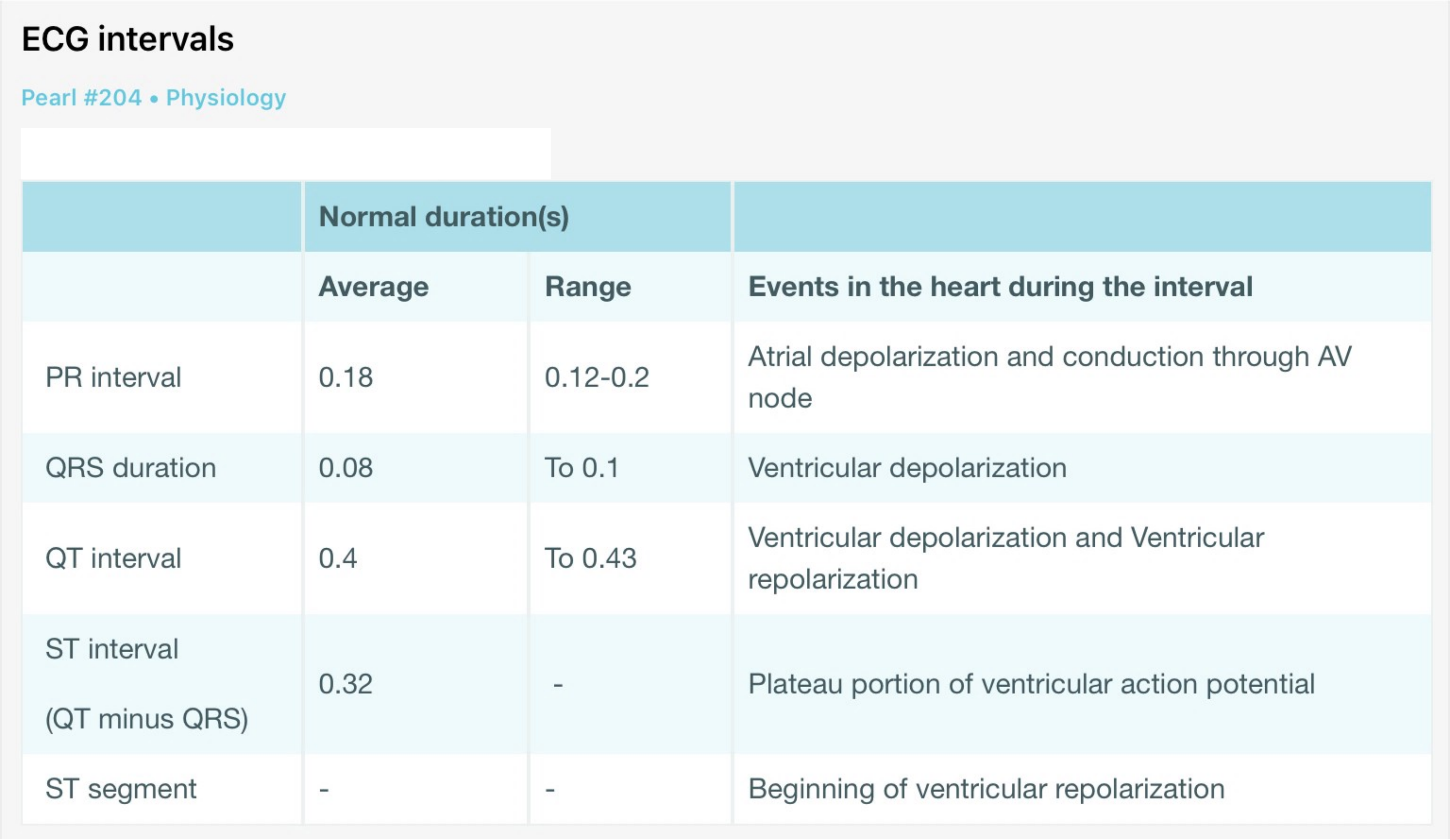
Type of Blood Pressure	Determinant
Systolic BP (SBP)	Stroke volume (directly proportional) Compliance of aorta (inversely proportional)
Diastolic BP (DBP)	Elastic recoil of aorta/major vessels (directly proportional)
Pulse pressure (PP)	Ratio of stroke volume to compliance of the arterial tree
Mean blood pressure (MAP)	Cardiac output Total peripheral resistance



Heart Blocks

Pearl #205 • Physiology

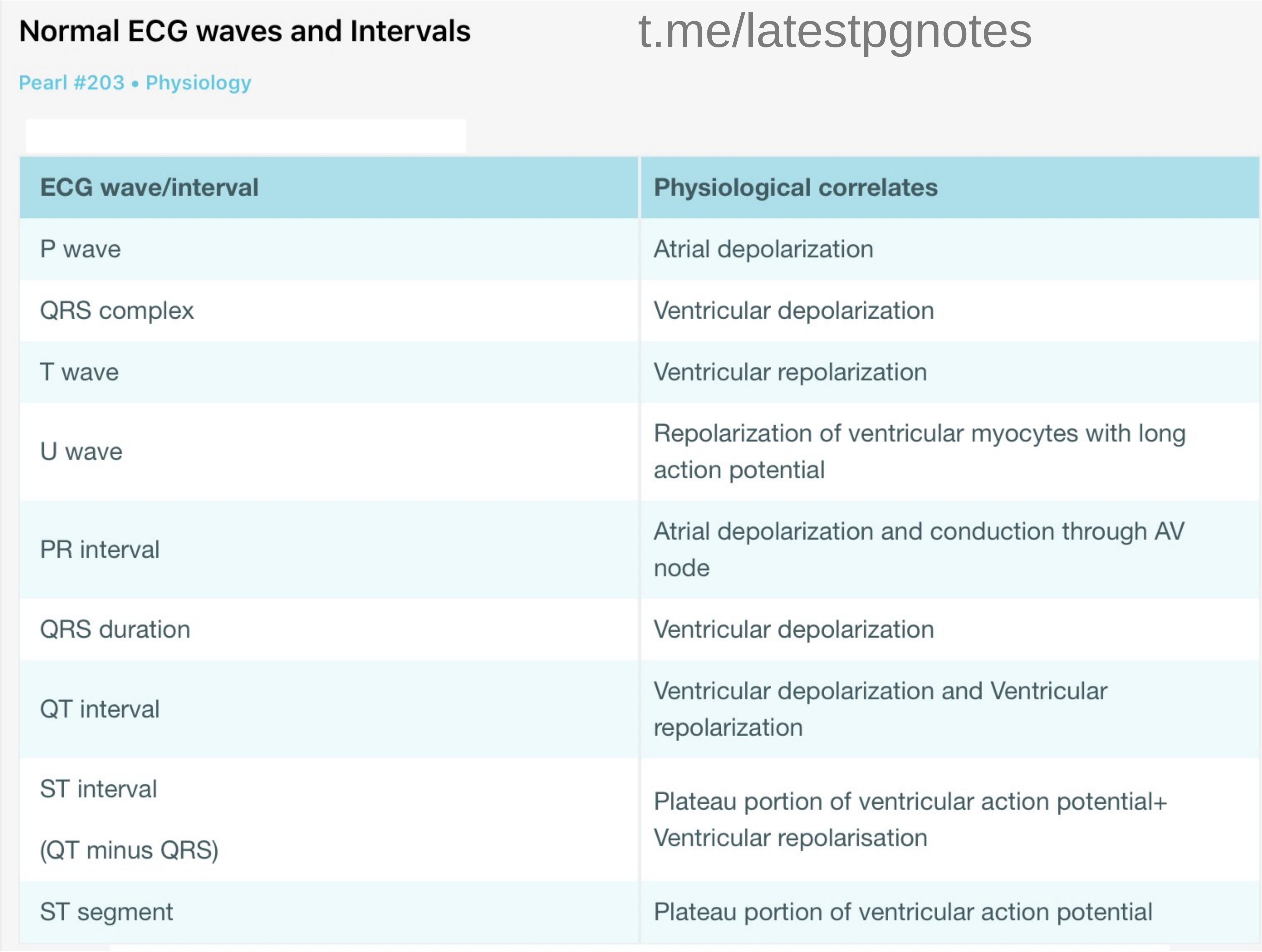
Type	Pathology	ECG features
First-degree block	All atrial impulses are conducted to ventricles but there is a delay	PR interval is constant and >0.2 sec
Second-degree block	not all atrial impulses are conducted to the ventricles	Atrial P waves present but no QRST wave (dropped ventricular beats)
Third-degree block (complete heart block)	Complete blockage of impulses from atria to ventricles	Dissociation between P wave and QRS complexes



ECG intervals

Pearl #204 • Physiology

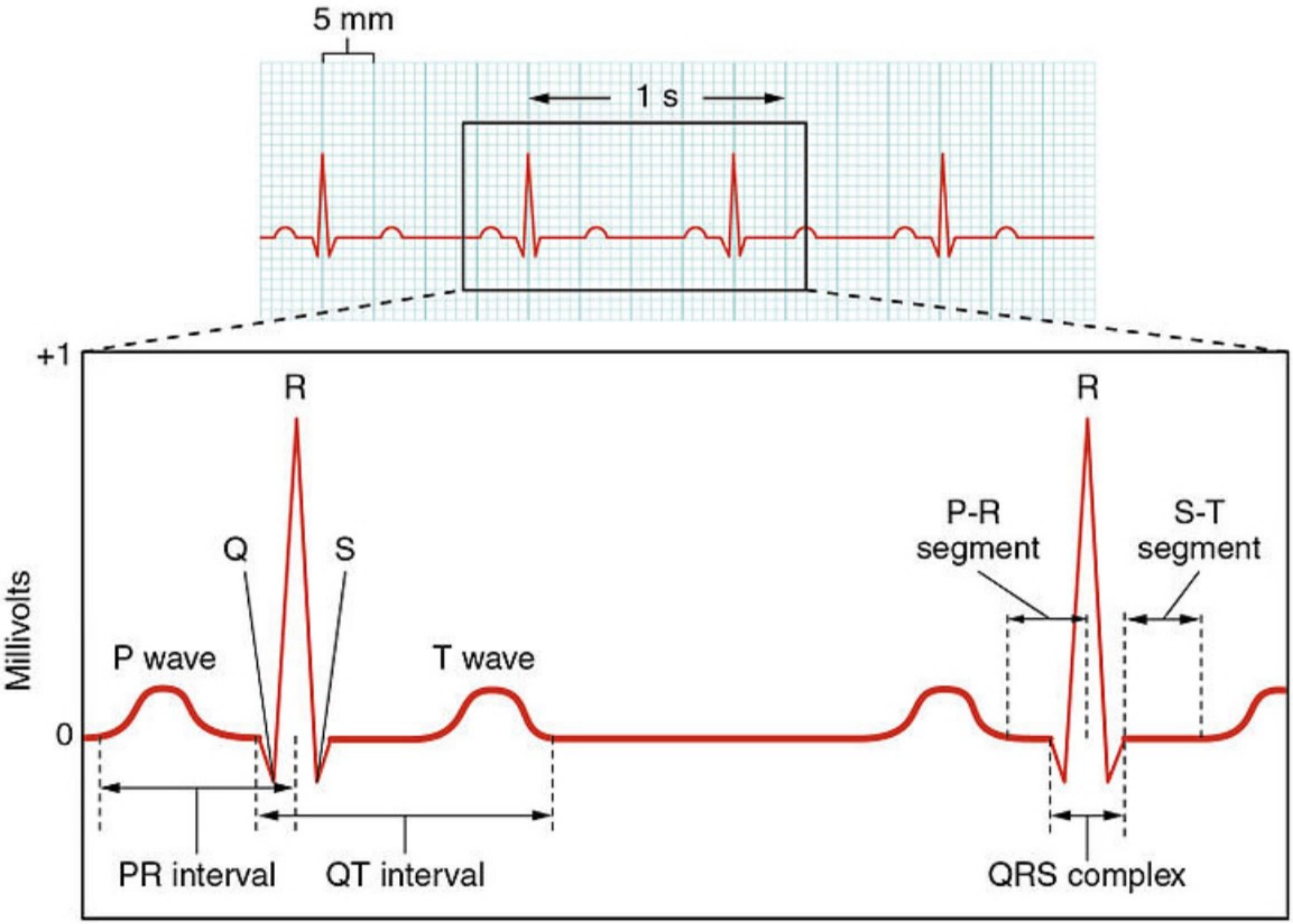
	Normal duration(s)		
	Average	**Range**	**Events in the heart during the interval**
PR interval	0.18	0.12-0.2	Atrial depolarization and conduction through AV node
QRS duration	0.08	To 0.1	Ventricular depolarization
QT interval	0.4	To 0.43	Ventricular depolarization and Ventricular repolarization
ST interval (QT minus QRS)	0.32	-	Plateau portion of ventricular action potential
ST segment	-	-	Beginning of ventricular repolarization

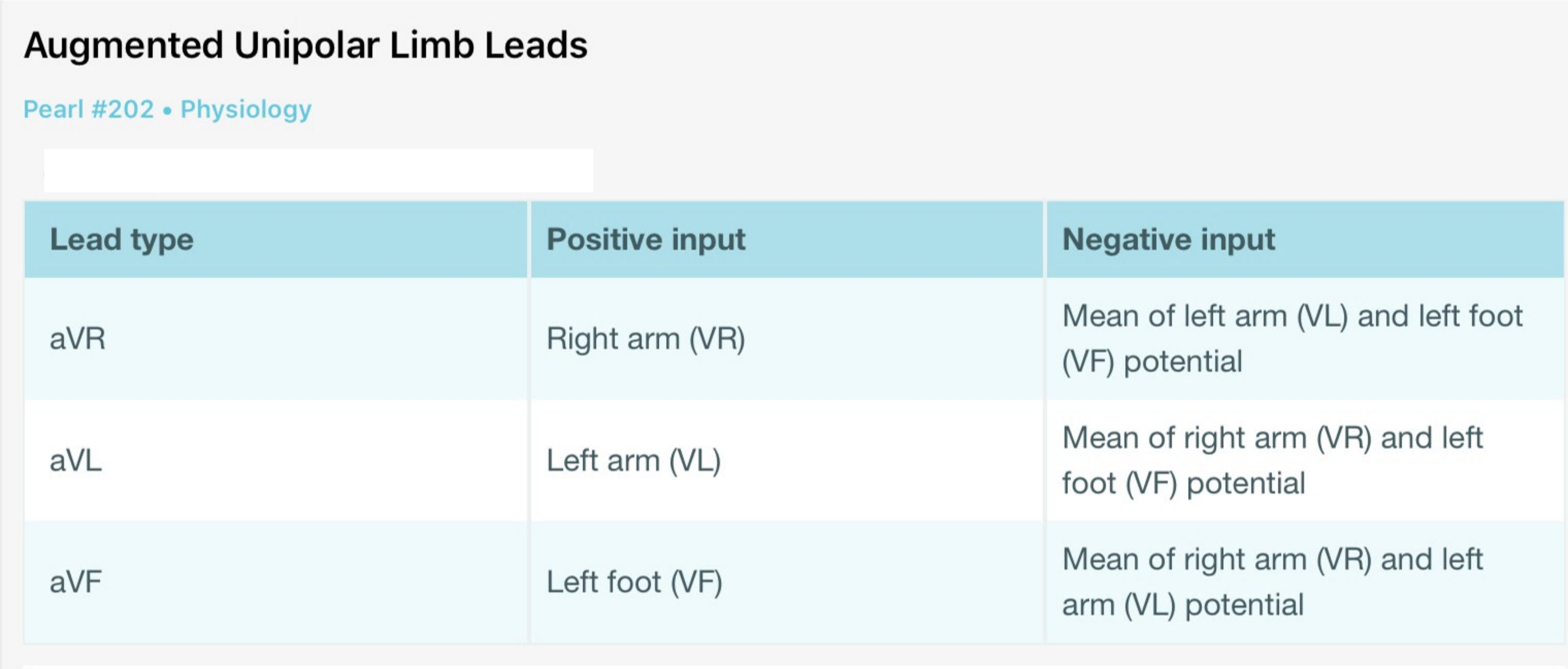


Normal ECG waves and Intervals

Pearl #203 • Physiology

ECG wave/interval	Physiological correlates
P wave	Atrial depolarization
QRS complex	Ventricular depolarization
T wave	Ventricular repolarization
U wave	Repolarization of ventricular myocytes with long action potential
PR interval	Atrial depolarization and conduction through AV node
QRS duration	Ventricular depolarization
QT interval	Ventricular depolarization and Ventricular repolarization
ST interval (QT minus QRS)	Plateau portion of ventricular action potential+ Ventricular repolarisation
ST segment	Plateau portion of ventricular action potential

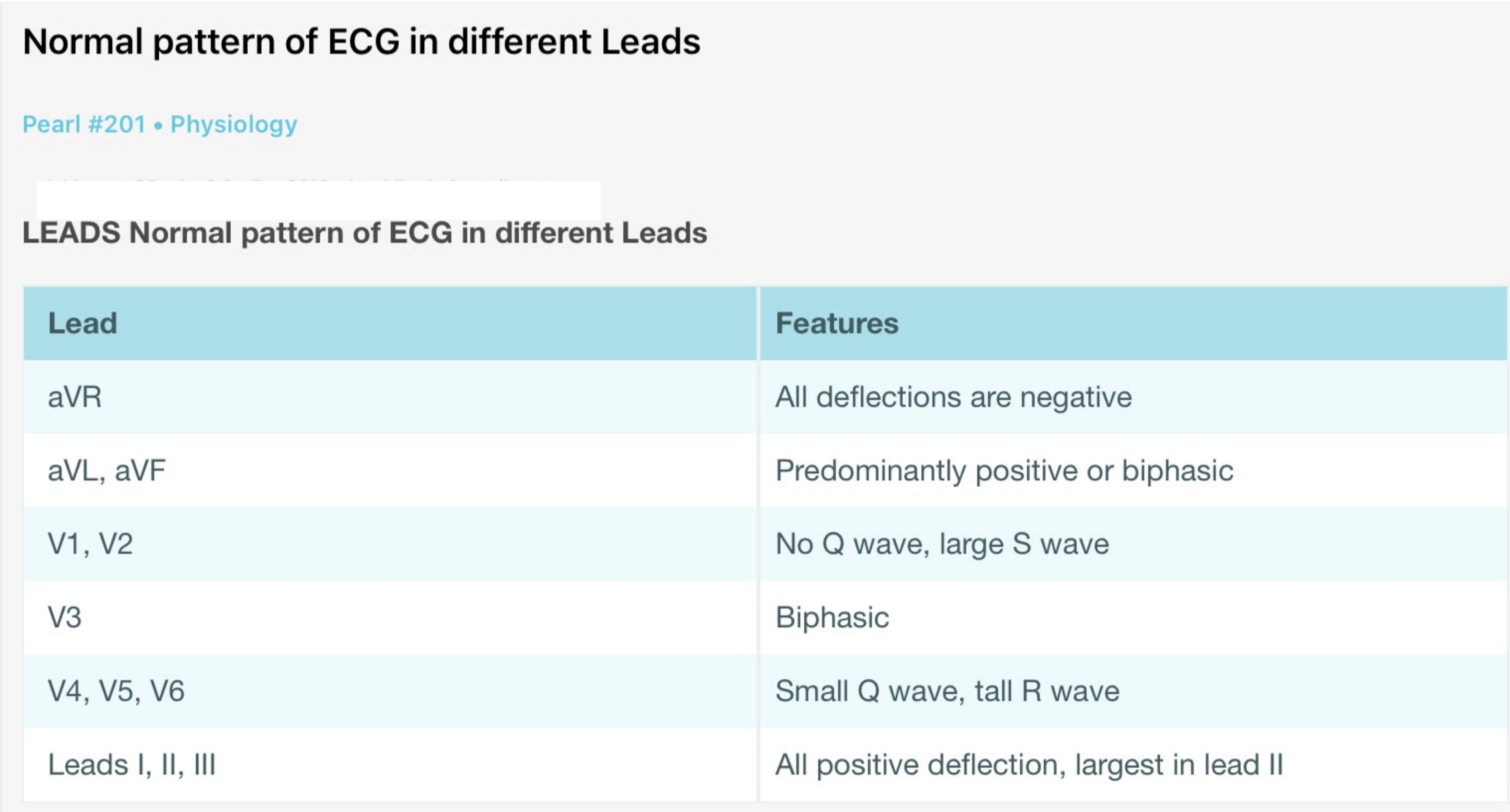

5 mm
1 s
+1
0
Millivolts
R
Q
S
P wave
T wave
R
P-R segment
S-T segment
PR interval
QT interval
QRS complex



Augmented Unipolar Limb Leads

Pearl #202 • Physiology

Lead type	Positive input	Negative input
aVR	Right arm (VR)	Mean of left arm (VL) and left foot (VF) potential
aVL	Left arm (VL)	Mean of right arm (VR) and left foot (VF) potential
aVF	Left foot (VF)	Mean of right arm (VR) and left arm (VL) potential

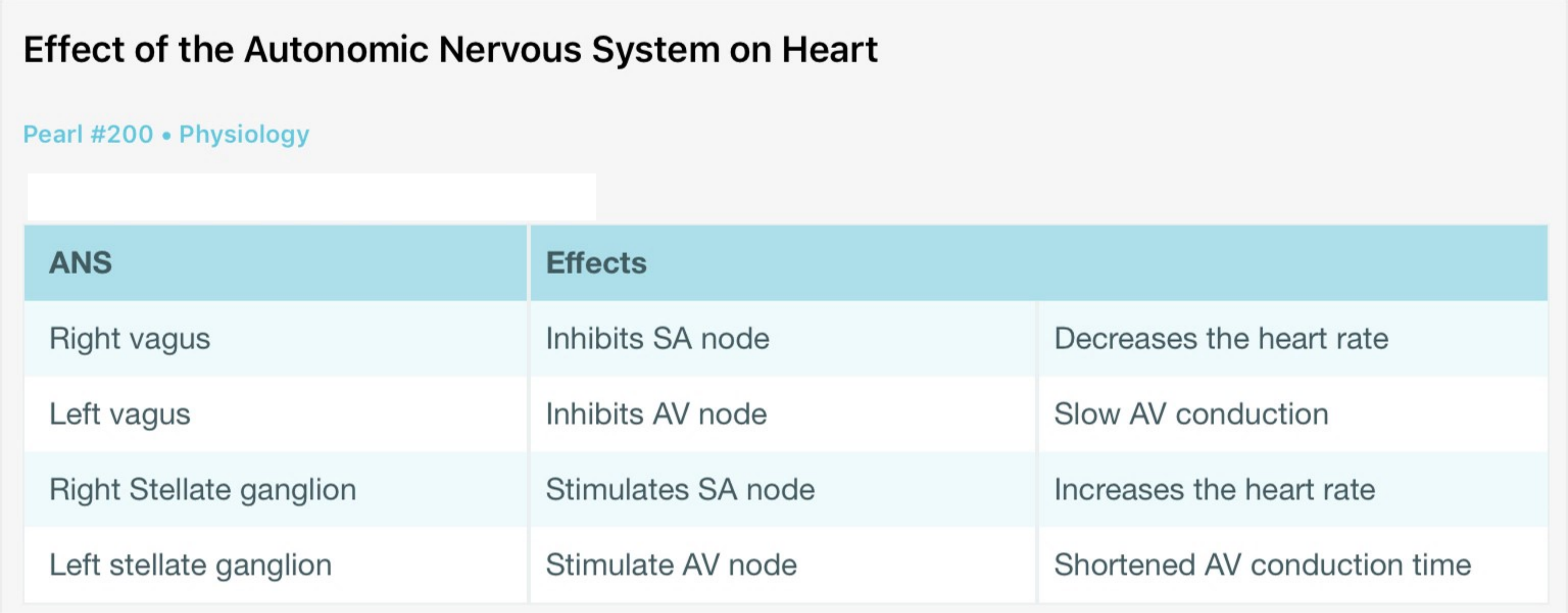


Normal pattern of ECG in different Leads

Pearl #201 • Physiology

LEADS Normal pattern of ECG in different Leads

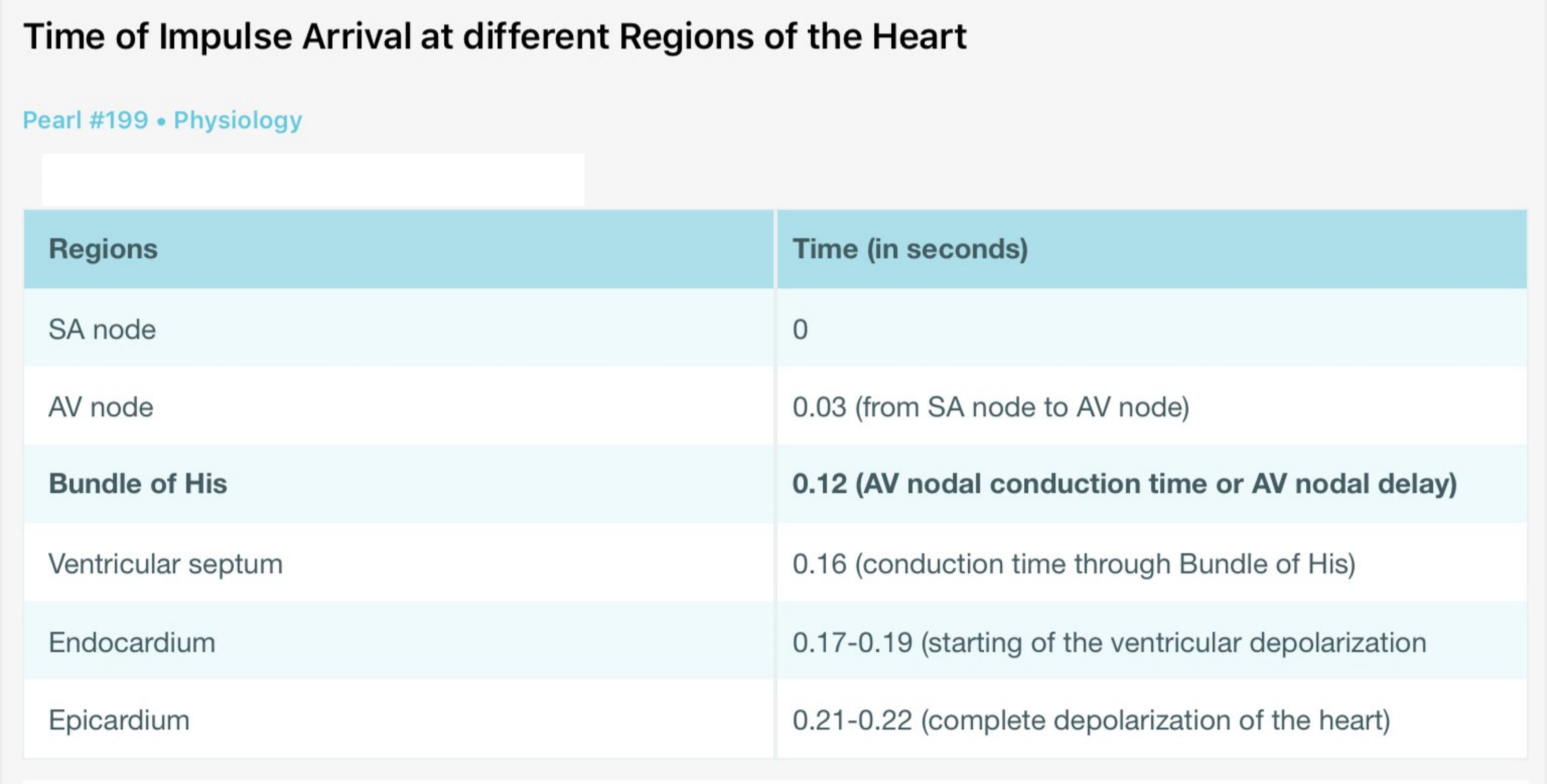
Lead	Features
aVR	All deflections are negative
aVL, aVF	Predominantly positive or biphasic
V1, V2	No Q wave, large S wave
V3	Biphasic
V4, V5, V6	Small Q wave, tall R wave
Leads I, II, III	All positive deflection, largest in lead II



Effect of the Autonomic Nervous System on Heart

Pearl #200 • Physiology

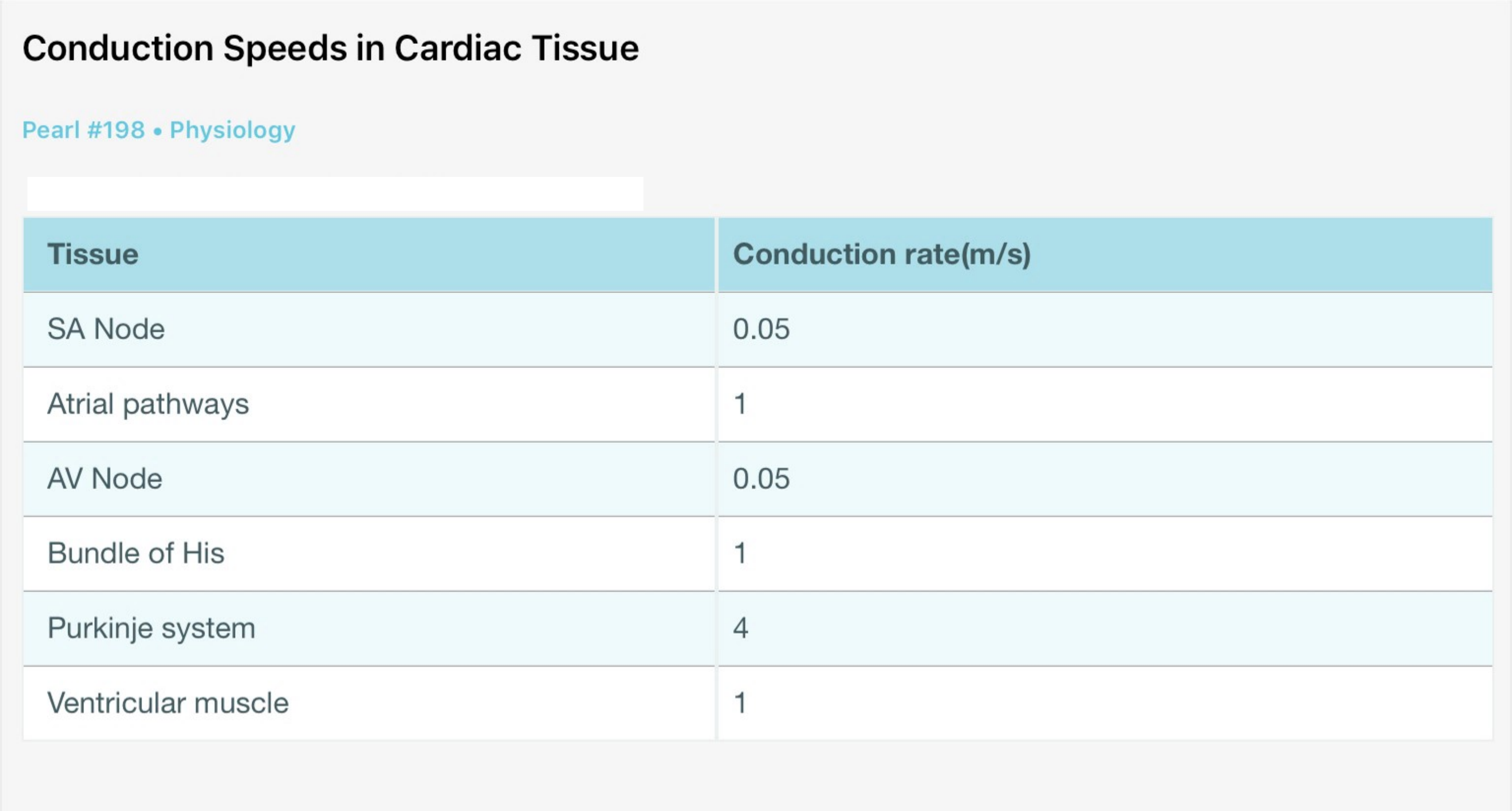
ANS	Effects	
Right vagus	Inhibits SA node	Decreases the heart rate
Left vagus	Inhibits AV node	Slow AV conduction
Right Stellate ganglion	Stimulates SA node	Increases the heart rate
Left stellate ganglion	Stimulate AV node	Shortened AV conduction time



Time of Impulse Arrival at different Regions of the Heart

Pearl #199 • Physiology

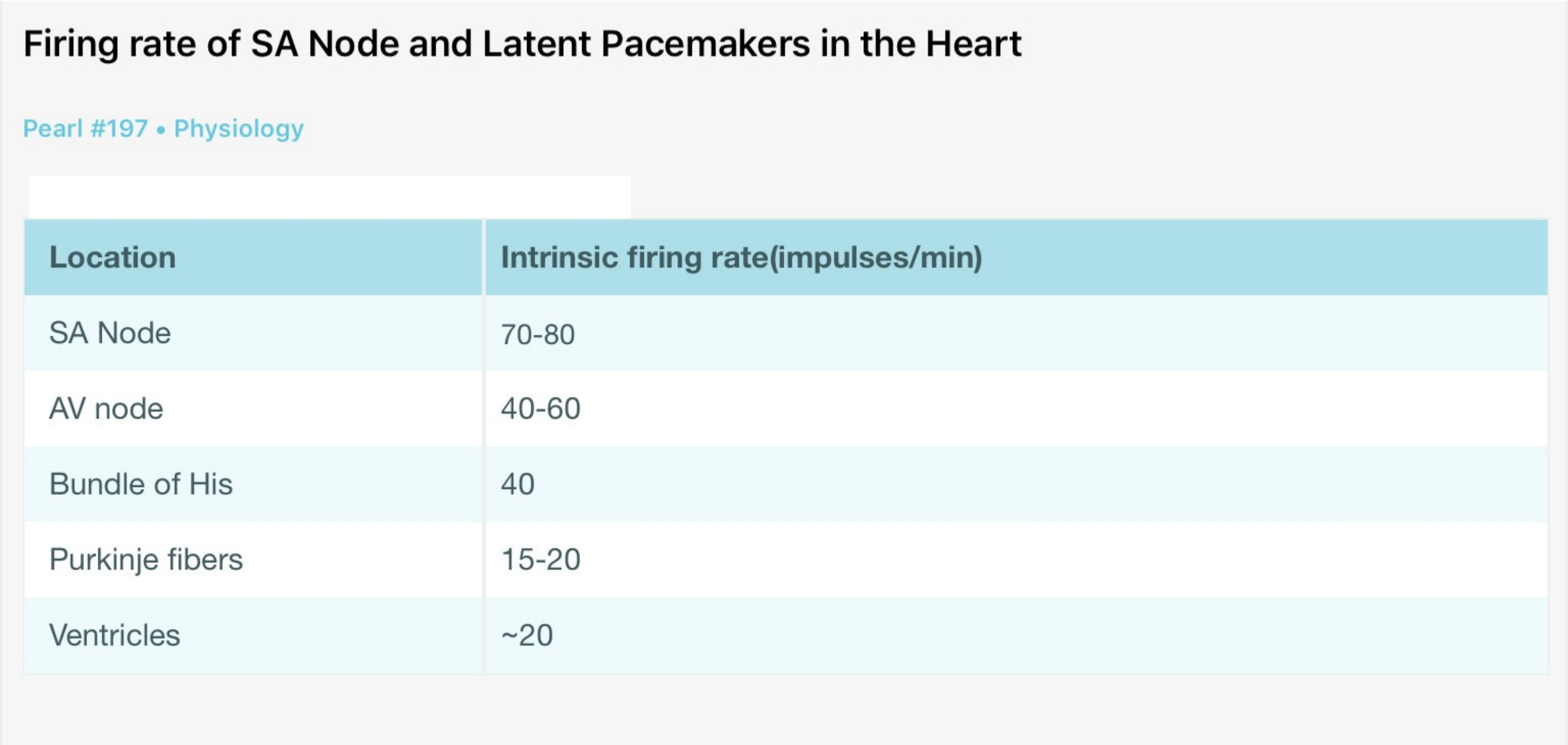
Regions	Time (in seconds)
SA node	0
AV node	0.03 (from SA node to AV node)
Bundle of His	**0.12 (AV nodal conduction time or AV nodal delay)**
Ventricular septum	0.16 (conduction time through Bundle of His)
Endocardium	0.17-0.19 (starting of the ventricular depolarization
Epicardium	0.21-0.22 (complete depolarization of the heart)



Conduction Speeds in Cardiac Tissue

Pearl #198 • Physiology

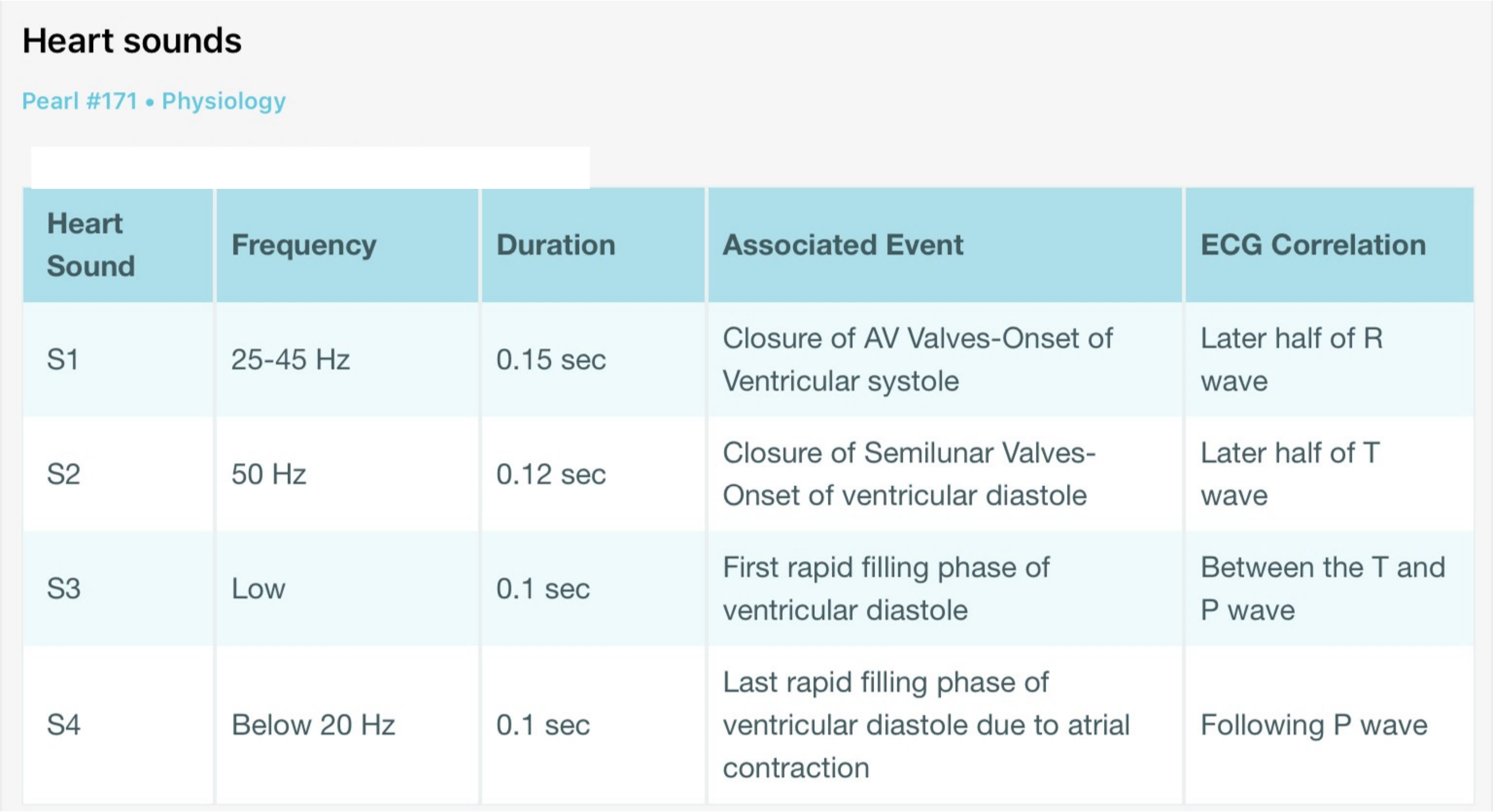
Tissue	Conduction rate(m/s)
SA Node	0.05
Atrial pathways	1
AV Node	0.05
Bundle of His	1
Purkinje system	4
Ventricular muscle	1



Firing rate of SA Node and Latent Pacemakers in the Heart

Pearl #197 • Physiology

Location	Intrinsic firing rate(impulses/min)
SA Node	70-80
AV node	40-60
Bundle of His	40
Purkinje fibers	15-20
Ventricles	~20



Heart sounds

Pearl #171 • Physiology

Heart Sound	Frequency	Duration	Associated Event	ECG Correlation
S1	25-45 Hz	0.15 sec	Closure of AV Valves-Onset of Ventricular systole	Later half of R wave
S2	50 Hz	0.12 sec	Closure of Semilunar Valves-Onset of ventricular diastole	Later half of T wave
S3	Low	0.1 sec	First rapid filling phase of ventricular diastole	Between the T and P wave
S4	Below 20 Hz	0.1 sec	Last rapid filling phase of ventricular diastole due to atrial contraction	Following P wave

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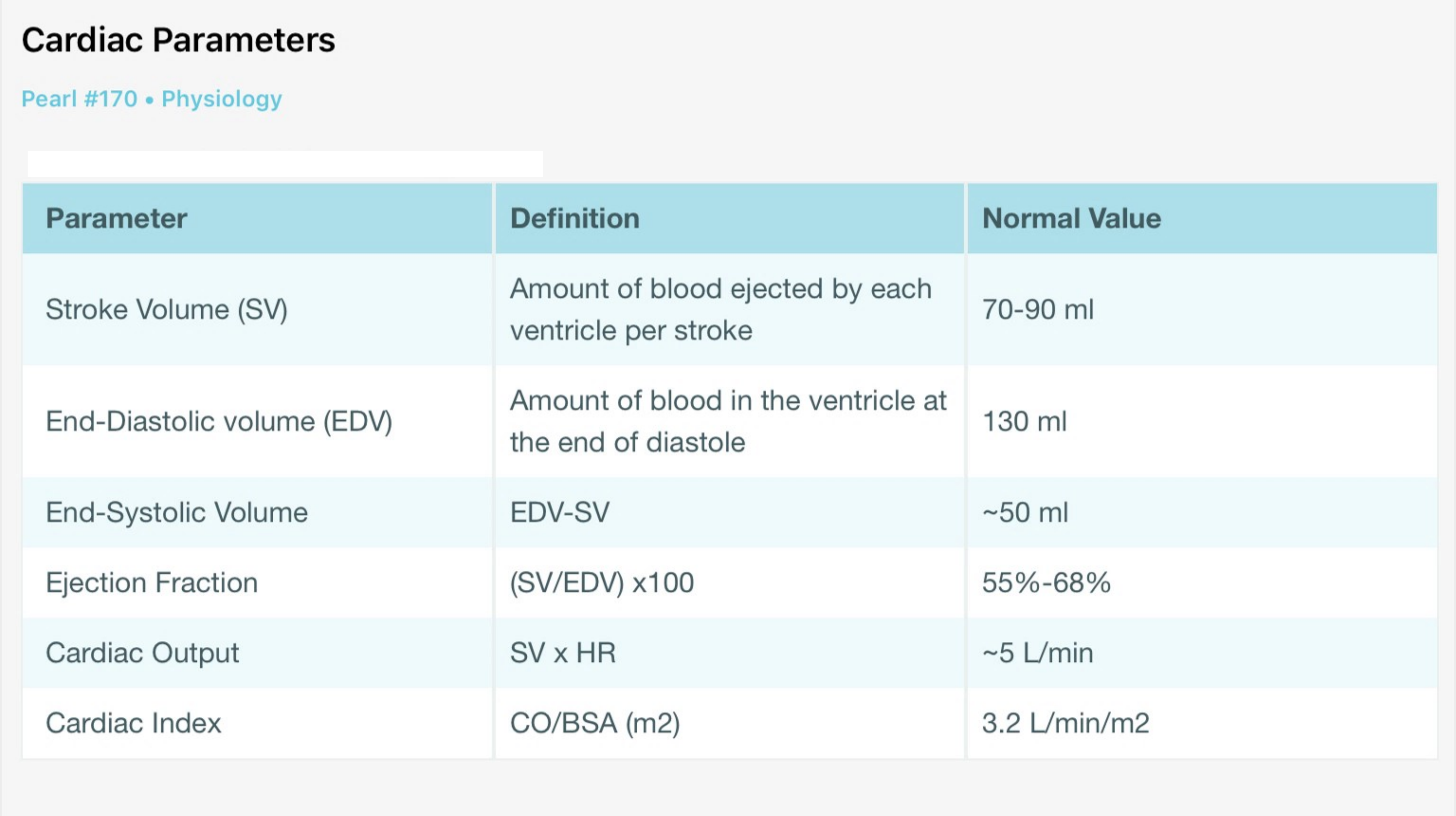
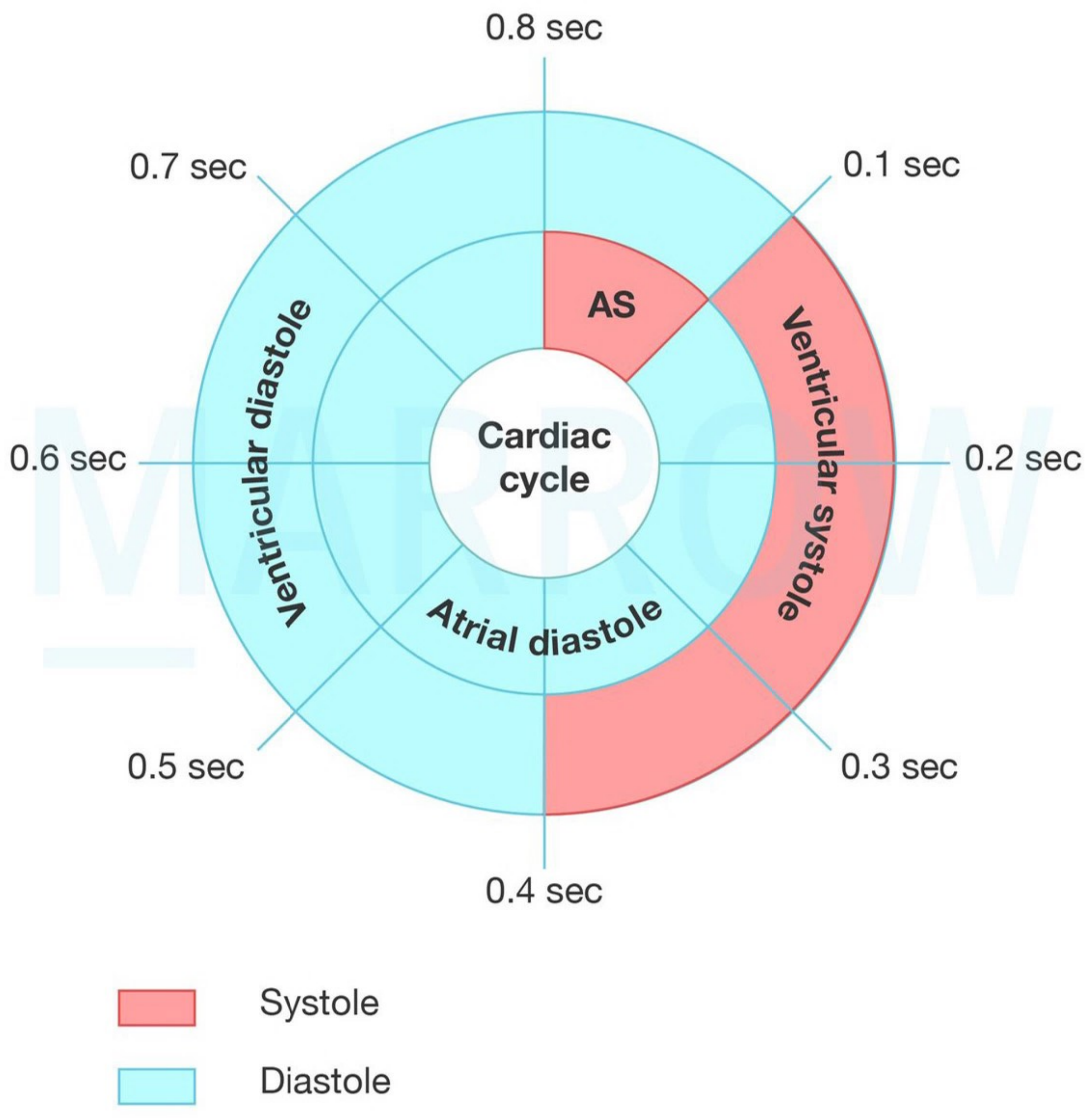


Cardiac Parameters

Pearl #170 • Physiology

Parameter	Definition	Normal Value
Stroke Volume (SV)	Amount of blood ejected by each ventricle per stroke	70-90 ml
End-Diastolic volume (EDV)	Amount of blood in the ventricle at the end of diastole	130 ml
End-Systolic Volume	EDV-SV	~50 ml
Ejection Fraction	(SV/EDV) x100	55%-68%
Cardiac Output	SV x HR	~5 L/min
Cardiac Index	CO/BSA (m2)	3.2 L/min/m2



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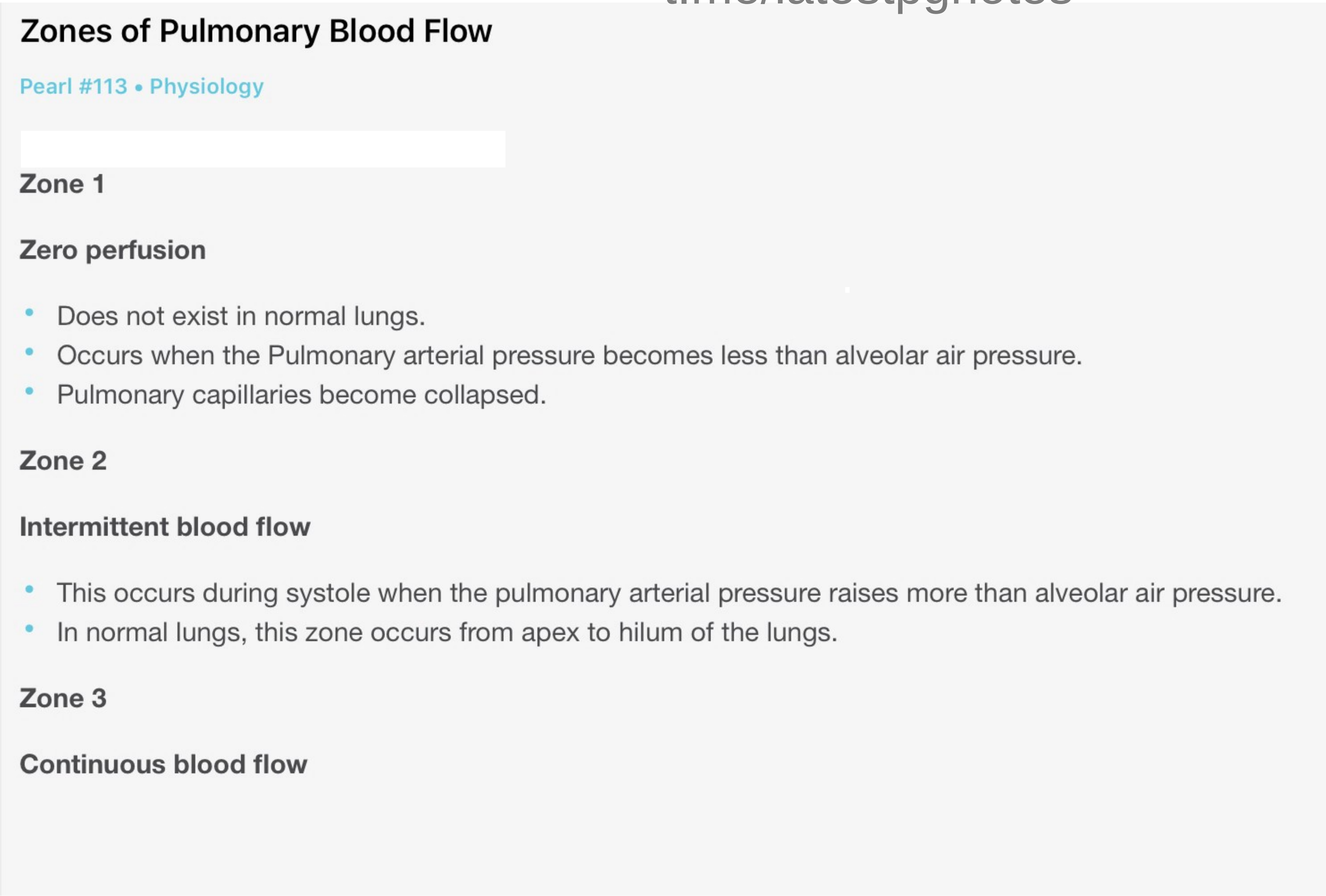
Cardiac Cycle Events	Systole(s)	Diastole(s)	Total (s)
Ventricles	0.3	0.5	0.8
Atria	0.1	0.7	0.8



Zones of Pulmonary Blood Flow

Pearl #113 • Physiology

Zone 1

Zero perfusion

- Does not exist in normal lungs.
- Occurs when the Pulmonary arterial pressure becomes less than alveolar air pressure.
- Pulmonary capillaries become collapsed.

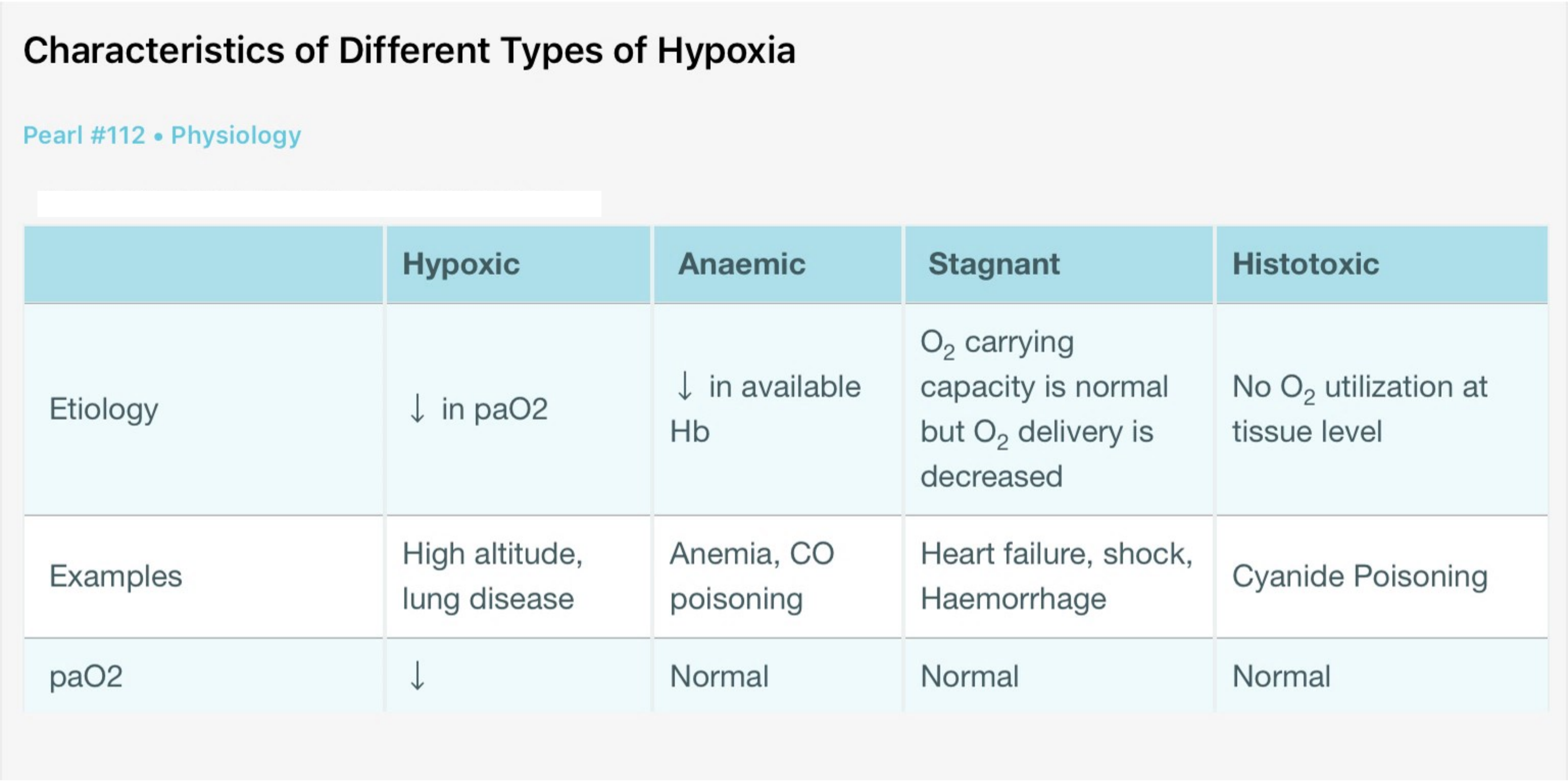
Zone 2

Intermittent blood flow

- This occurs during systole when the pulmonary arterial pressure raises more than alveolar air pressure.
- In normal lungs, this zone occurs from apex to hilum of the lungs.

Zone 3

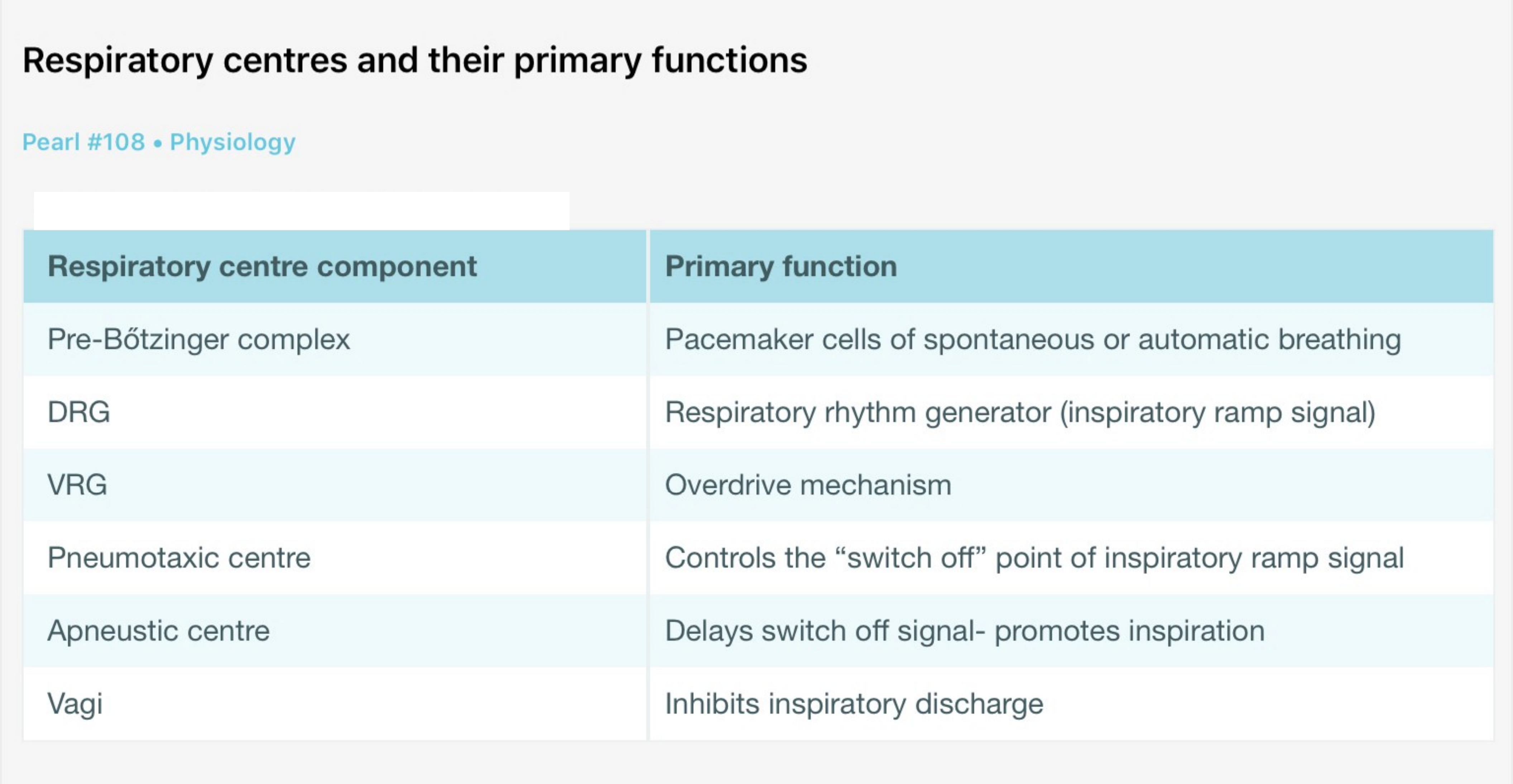
Continuous blood flow



Characteristics of Different Types of Hypoxia

Pearl #112 • Physiology

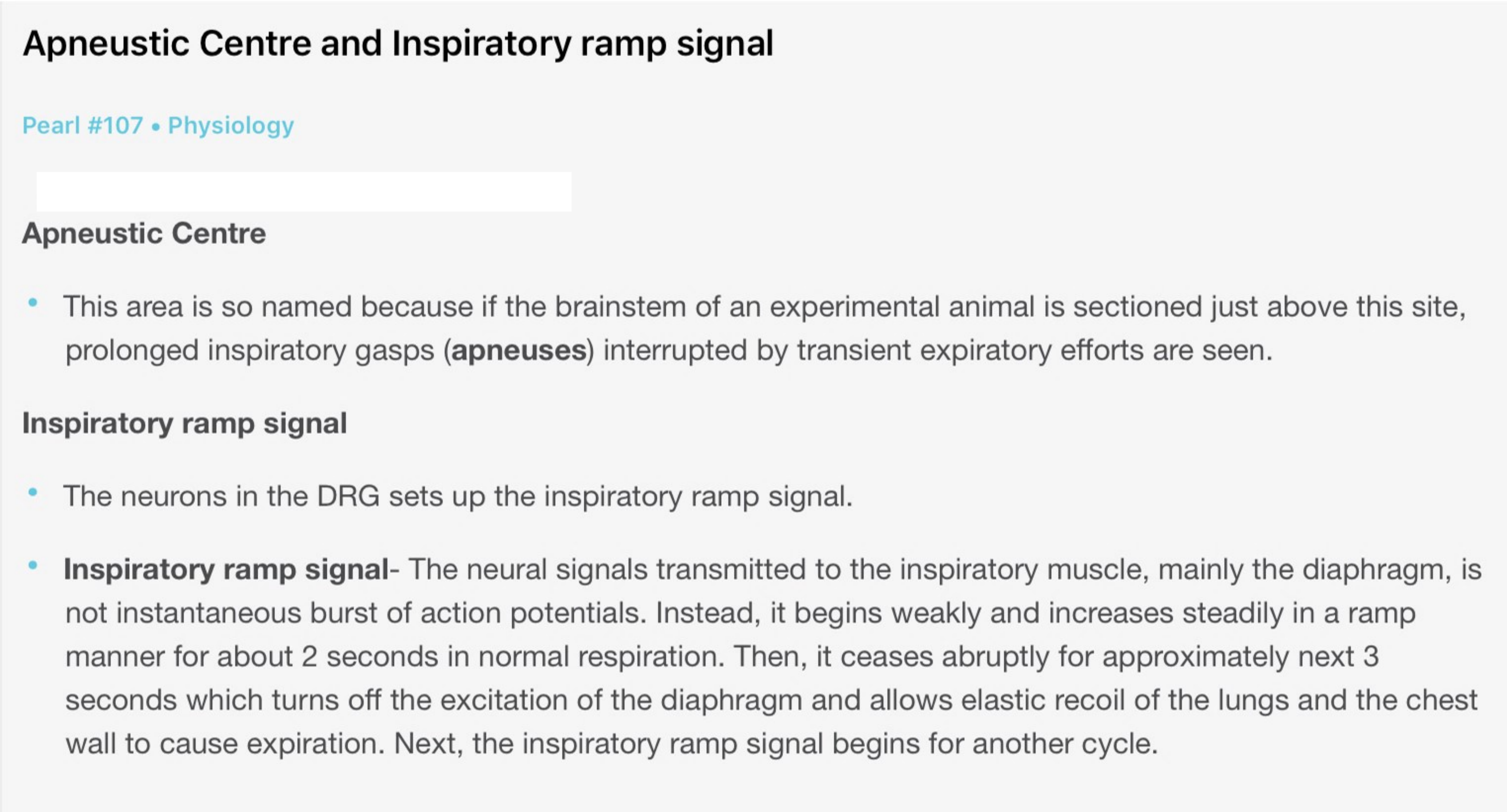
	Hypoxic	Anaemic	Stagnant	Histotoxic
Etiology	↓ in paO2	↓ in available Hb	O_2 carrying capacity is normal but O_2 delivery is decreased	No O_2 utilization at tissue level
Examples	High altitude, lung disease	Anemia, CO poisoning	Heart failure, shock, Haemorrhage	Cyanide Poisoning
paO2	↓	Normal	Normal	Normal



Respiratory centres and their primary functions

Pearl #108 • Physiology

Respiratory centre component	Primary function
Pre-Bőtzinger complex	Pacemaker cells of spontaneous or automatic breathing
DRG	Respiratory rhythm generator (inspiratory ramp signal)
VRG	Overdrive mechanism
Pneumotaxic centre	Controls the “switch off” point of inspiratory ramp signal
Apneustic centre	Delays switch off signal- promotes inspiration
Vagi	Inhibits inspiratory discharge



Apneustic Centre and Inspiratory ramp signal

Pearl #107 • Physiology

Apneustic Centre

- This area is so named because if the brainstem of an experimental animal is sectioned just above this site, prolonged inspiratory gasps (**apneuses**) interrupted by transient expiratory efforts are seen.

Inspiratory ramp signal

- The neurons in the DRG sets up the inspiratory ramp signal.
- **Inspiratory ramp signal**- The neural signals transmitted to the inspiratory muscle, mainly the diaphragm, is not instantaneous burst of action potentials. Instead, it begins weakly and increases steadily in a ramp manner for about 2 seconds in normal respiration. Then, it ceases abruptly for approximately next 3 seconds which turns off the excitation of the diaphragm and allows elastic recoil of the lungs and the chest wall to cause expiration. Next, the inspiratory ramp signal begins for another cycle.